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THE GENERAL AVIATION DYNAMICS MODEL VOLUME II. TECHNICAL REPORT--ETC(U)

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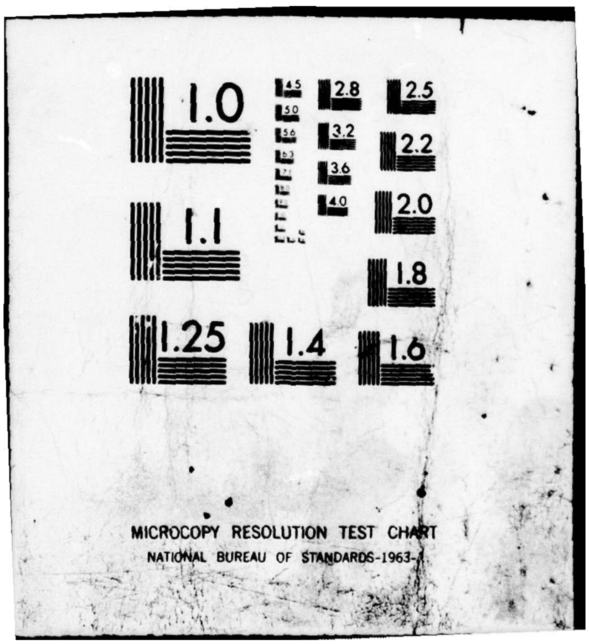
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THE GENERAL AVIATION DYNAMICS MODEL

Volume II. Technical Report

July 1979

FINAL REPORT

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Office of Aviation Policy
Aviation Forecast Branch
Washington D.C. 20591

The contents of this report reflect the views of Battelle's Columbus Laboratories, which is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policy of the Department of Transportation. This report does not constitute a standard, specification, or regulation.

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16. Abstract

The model is a dynamic simulation, interactive computer, model built upon the cause-effect interactions displayed between various sectors of the general aviation system. The initial work by Battelle in 1976 was based on data through calendar year 1974 (Report No. FAA-AVP-77-20, General Aviation Dynamics .... April 1977, three volumes).

Under this contract, the model was updated based on data through 1976 and the results are presented in a two volume technical document covering the current model development efforts and all prior work done by Battelle.

Volume I: Executive Summary

- is given.

BEGIN HERE

Volume II: Technical Report-provides a detailed description of the General Aviation Dynamics (GAD) model. It contains a complete set of statistics, including actual data, for the estimated causal relationships within each sector of the model. ~~Volume II~~ also illustrates how the GAD model can be used to evaluate alternative policy actions.

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FINAL REPORT

on

THE GENERAL AVIATION DYNAMICS MODEL

VOLUME II. TECHNICAL REPORT

to the

OFFICE OF AVIATION POLICY
FEDERAL AVIATION ADMINISTRATION

May 30, 1979

by

Michael A. Duffy

(CONTRACT NO. DOT-FA77WA-4043)

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Columbus, Ohio 43201

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

LIST OF TABLES

LIST OF TABLES
(Continued)

LIST OF TABLES
(Continued)

LIST OF FIGURES

LIST OF FIGURES
(Continued)

LIST OF FIGURES
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LIST OF ENDOGENOUS VARIABLES

AA(I,J)	Active aircraft; user category I, aircraft type J
ATCIN	Airline transport certificates issued normal
ATP	Airline transport pilots
ATPDN	Airline transport pilot departures normal
AURN(I,J)	Aircraft utilization rate normal
CCIN	Commercial certificates issued normal
CP	Commercial pilots
CPDN	Commercial pilot departures normal
DAA(I,J)	Desired active aircraft
DAUR(I,J)	Desired aircraft utilization rate
DPPA(I,J)	Desired pilots per aircraft
HCI	Helicopter certificates issued
HF(I,J)	Hours flown(annual)
HPDN	Helicopter pilot departure normal
HRI	Helicopter ratings issued
HRIN	Helicopter ratings issued normal
IPDN	Instrument-rated pilot departures normal
IRI	Instrument ratings issued
PCI	Private certificate issued
PCIN	Private certificates issued normal
PP	Private pilot
PPDN	Private pilot departures normal
SCI	Student certificate issued
SCIN(K)	Student certificates issued normal
SPDN	Student pilot departures normal
T	Time
URIPN	Upgrade rate to instrument-rating from private normal

LIST OF EXOGENEOUS VARIABLES

DPI	Disposable personal income (per capita) Indexed to 1972 value and measured in constant 1972 dollars
FC(J)	Fixed cost of ownership; indexed to 1972 value and measured in constant 1972 dollars
FIXINF	Fixed cost inflation factor
GNP	Gross national product, indexed to 1972 value and measured in constant 1972 dollars
RAD	Revenue aircraft departures, indexed to 1972 value
SCIMULT	Student certificate issued multiplier
SFC(J)	Specific fuel consumption (gallons/hour)
TC(I,J)	Total cost of owning and operating aircraft, indexed to 1972 value and measured in constant 1972 dollars
TCP(I,J)	Total cost previous year, indexed to 1972 value and measured in constant 1972 dollars
VC(J)	Variable cost of operating aircraft, indexed to 1972 value and measured in constant 1972 dollars
VCINF	Variable cost inflation factor

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CHAPTER 1. INTRODUCTION

The United States General Aviation fleet is comprised of all civil aircraft except those operated in the air carrier system. General aviation has had a tremendous influence on the American way of life: in travel time, in technology, in jobs, in fulfilling the transportation needs of a mobile society. By virtually any standard, the general aviation system within the United States is a large, diverse, and complex group of people, equipment, and activities. It encompasses a fleet of over 178,000 aircraft, flying nearly 4-1/2 billion miles, consuming more than 900 million gallons of fuel, and performing over 100 million operations during 1976.

Much of its influence, nevertheless, remains noticeably misunderstood and unexplored. A comprehensive definition of general aviation by the Federal Aviation Administration (FAA) is "the use of aircraft for purposes other than commercial transportation certificated by the Civil Aeronautics Board, intrastate commercial operations by large aircraft on regularly scheduled routes, or military use". Commuter

airlines and air taxi operations are included in the term general aviation. General aviation operations encompass an extremely wide range of activity. The aircraft are used for purposes ranging from purely recreational flying to air taxi service and corporate-owned executive transportation. In contrast to the interest shown in the activities of the commercial airlines, general aviation has been largely ignored by analysts outside of the FAA and the industry itself. The lack of scholarly attention to general aviation is surprising when one considers its importance. This importance is substantiated by any conceivable measure one cares to make, whether number of aircraft, mileage or hours flown, landings and take-offs, industry employment, net exports, etc.

In 1976 general aviation accounted for 98.6 percent of all civil aircraft registered in the United States. Furthermore, it is the fastest growing segment of the national aviation system, averaging a 5.3 percent per year increase in active aircraft over the last 4 years. The FAA estimates that in 1976, 4.5 billion aircraft miles were flown by general aviation, compared to 2.0 billion revenue aircraft miles for scheduled domestic service by the air carriers in the same year. During 1976, general aviation aircraft, despite their ability to make use of landing strips with no FAA facilities at all, made 75 percent of the landings and takeoffs recorded by FAA-operated control towers.

Even more surprising to those who believe that high air traffic density is confined to the large air carrier airports such as Chicago (O'Hare), Los Angeles, and New York, will be the information supplied in Table 1, which lists the leading FAA-operated air traffic control towers in rank order of total operations for 1975 (1). This table highlights how little is known about general aviation, for few people would place Santa Ana in such a high position among the better known airports. The high rankings of Van Nuys, and Long Beach, all of which have more total operations than Los Angeles International, are due entirely to the volume of general aviation activity at these airports.

TABLE 1. LEADING FAA-OPERATED AIRPORT TRAFFIC CONTROL TOWERS IN RANK ORDER OF TOTAL AIRCRAFT OPERATIONS DURING 1975

Tower	Total Operation
Chicago O'Hare International	668,368
Santa Ana, California	618,889
Van Nuys, California	588,098
Long Beach, California	538,230
Atlanta International	469,499
Los Angeles International	455,836
Phoenix Sky Harbor International	430,004
San Jose Muni, California	430,004
Opa Locka, Florida	425,783
Torrance Muni, California	409,858

General aviation does not exist in a vacuum independent of other influences, but is controlled by Congressional action and extensive mandatory regulation. Economic factors influence airport administration and finance. Vehicle airworthiness certification costs are becoming increasingly burdensome. Rising costs of nearly all goods and services necessitate close scrutiny of expenditures. Protection of the environment, such as lowering of noise levels, natural resource depletion prevention, and the preservation of clean and fresh water are all concerns of general aviation.

REVIEW OF AVIATION FORECASTING

Accurate forecasts of general aviation activity are important to the FAA, the manufacturers of general aviation aircraft and equipment, fuel suppliers, and airport operators. The FAA relies on short-term forecasts of national aviation activity to support the budgetary process, whereas long-term forecasts are used in the research and development planning process. Of primary importance is an accurate

assessment of the expected future growth of general aviation. These forecasts, already complex, become extremely difficult when evaluating possible alternative federal policies.

Early methods for forecasting future general aviation activity relied mainly on trend extrapolations - hardly adaptable to policy analysis. In 1968 R. Dixon Speas reported that "it is significant that, apart from the FAA forecast, there have been but several other rather cursory forecasts available to the public covering this very large and important part of the aviation industry" (2). In fact, the FAA's forecast for the period 1968 to 1979 shows a net addition to the fleet of 8,000 units annually, throughout the forecast period. The FAA apparently tried at that time to establish correlations with the major economic indicators - particularly Gross National Product - but was unsuccessful. However, Speas did develop a simple linear equation relating general aviation fleet size Y (measured in thousands of aircraft) as a function of GNP during the previous year (measured in billions of current dollars)

$$Y = 7.71 + 0.153 * GNP$$

Forecasts of the total fleet projected with the equation were then disaggregated by aircraft type, by applying historical annual growth rates for each aircraft category. Speas also produced a forecast of annual hours flown by estimating annual growth rates in utilization per aircraft as a function of aircraft type. Finally, Speas developed active airmen forecasts by ratioing the number of active pilots to the number of active aircraft, and assuming that the trend of this ratio would continue to increase modestly in the future. They also developed forecasts of numbers of aircraft and hours of operation by type of use from evaluation of historical trends.

In a Brookings Institution study of public policy toward general aviation published by Warford in 1971 (3), he acknowledged that the FAA's general aviation forecasts rely largely upon extrapolation of past trends. Apart from relatively minor adjustments, the extrapolation method implies that the influence of changes in those variables

affecting the use of airport and airway facilities will follow the same trend as in the past. This is particularly alarming to Warford, who was trying to build a case for adopting new federal policies of cost recovery. However, Warford states (without any references) that "attempts to use time series data to derive price elasticity estimates for various measures of general aviation activity have consistently come up with statistically insignificant price coefficients".

Perhaps the first comprehensive treatment of the determinants of the demand for general aviation was published by Ratchford in 1972 (4). He developed a method for measuring the quantity and price of general aviation services, and then estimated the price and income elasticity of demand for general aviation services. Ratchford recognized that the various types of users of general aviation are unlikely to be affected in exactly the same way by price and income changes. Unfortunately, with the existing time series data, it was possible only to obtain estimates of the influence of price, income, and other variables on the aggregate demand for general aviation. Several alternative demand functions for general aviation services were constructed according to the following form:

$$Q_t^* = f(L_t^*, I_t, M_t, D_p, D_k, U)$$

where U is a random error term, Q_t^* is the quantity of general aviation services consumed per capita in year t, L_t^* is the relative price of general aviation services in year t, I_t is a measure of real income in year t, M_t is the relative price of commercial air travel, and D_p and D_k are dummy variables capturing the impact of post World War II G.I. bill pilot training programs and the Korean war. Rather than positing a certain "best" model, the main conclusions of this study were that the income elasticity of demand for general aviation services with respect to permanent income is at least 2.5 and the price elasticity of demand for general aviation is between -1.5 and -2.0.

In June, 1973, Battelle published "The General Aviation Cost Impact Study" (5) which was to provide the FAA with a means for estimating the effects of cost changes on general aviation activity. In

funding this study, the FAA recognized the importance of continual efforts to improve forecasts for planning within both the FAA and the aviation community. The approach was ambitious, but the results not terribly useful. Elasticity measures for the variable costs of operation and the fixed cost of ownership were developed for each of eleven different aircraft types within eight distinct user categories. Activity within each of the 88 general aviation subsegments was measured in terms of the number of active aircraft and the annual hours flown. By using the stock of active aircraft as the dependent variable, positive autocorrelation problems occur leading to estimated coefficients with spuriously high significances. A better procedure, often used in estimating demand of capital stocks, is to use net investment in aircraft (change in fleet size) as the dependent variable. Similarly, average aircraft utilization (hours/year/aircraft) is a better dependent variable than the aggregate annual hours flown. Nevertheless, this Battelle study represented a milestone in assembling a consistent time series data base for active general aviation aircraft and their respective operational and ownership costs.

In December, 1975, the FAA held its First Annual Aviation Forecast Conference (6). During the conference FAA personnel presented highlights of then current aviation forecasts and the methods upon which these forecasts were based. In particular, a newly developed econometric general aviation forecasting model was unveiled. Basically, the model consists of a set of thirteen linear multiple regression equations. Various general aviation activity measures are related, either directly or indirectly, to the performance of the U.S. economy. The tone of the entire model can be captured by examining the single equation for forecasting the active fleet size,

$$GAAA = -1965.16 + 43.10\ CMP + 33.27\ PAC - 0.02\ SUB$$

where GAAA represents the number of general aviation aircraft, CMP the number of civilians employed, PAC the plant and equipment expenditures in the aircraft industry, and SUB is the factory sales of automobiles. Such a model leaves much to be desired when attempting to better

understand system behavior, or when evaluating alternative federal fiscal policies. Models are needed that explain individual behavior within the general aviation system, not merely correlate well with the data.

The following year FAA was still using this same basic set of equations to forecast general aviation activity. Estimated values of the coefficients were in some cases significantly different from the estimated values in the original model. Such parameter instability indicates a model of limited usefulness.

The current FAA general aviation forecasting model is based on the same set of thirteen linear multiple regression equations. Some adjustment of the independent variables has been made. For example, the equation for predicting the number of general aviation aircraft is "based on the stock adjustment principle"; that is, net additions to the fleet depend on a desired fleet size, the number of active aircraft in the previous year, and the rate of adjustment which measures how quickly the aviation community can respond to changes in the desired fleet size.

POLICY MODELING

Under the provisions of the 1958 Federal Aviation Act, the Federal Aviation Administration has responsibility for the construction and operation of the airways system, which consists of air traffic control, navigational and other flight aids and services, and a vast communications network. The FAA also has power under the act to establish regulations and air traffic rules to control all civil and military operations throughout the navigable airspace of the United States, as well as to establish and administer regulations concerning safety standards for aircraft, the qualification of airmen, and standards for flying schools. It also has the important function of carrying out and supervising research and development with respect both to aircraft and air navigation facilities, and acting as a source of information on this and related matters to the aviation industry. This is in accordance with the general duty, specified in the legislation, that the FAA

administrator should "encourage and foster the development of civil aeronautics and air commerce in the United States and abroad".*

The need for accurate general aviation activity forecasts is obvious. These forecasts, already complex, become extremely difficult when evaluating possible alternative federal policies.

A forecast is a prediction of what the future will be. It is usually independent of any actions that might be taken as a result of the forecast. But forecasts are used as inputs to decision making. Thus, forecasts are often either self-fulfilling or self-defeating, but almost never autonomous.

Forecasts are a necessary input to the policy evaluation process, but a thorough planning exercise requires more. Policy evaluation requires models which describe the causal relationships characteristic of actual decision processes in the real system. In order to properly evaluate alternative policy actions, a comprehensive understanding of the system is required and adequate flexibility in its representation is desired.

Most econometric forecasting models have been founded on Lockean principles, emphasizing the use of empirical data. An econometric model literally grows out of the data. Estimation of the coefficients of the model, specification of the equations, testing of the model, all hinge on having a full set of data available on both the endogenous and exogenous variables. The availability of formal data is therefore a critical factor to the econometrician in deciding what variables to include.

Being data dependent, econometric modeling makes extensive use of time series data. Although the existence of such data has stimulated the development of econometric models of the national economy, the lack of data has been an impediment to model building elsewhere - especially within the general aviation system. Allegiance to time series or cross-sectional data limits the choice of variables. When formal data on the reference system being modeled are unreliable or difficult to come by,

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*Federal Aviation Act of 1958, sec. 305 (72 stat-749).

as in general aviation, econometric modeling is at a disadvantage compared to modeling methodologies that are not as data dependent.

System dynamic models have primarily followed the Leibnitzian approach which emphasizes structural definition of the model. Classical system dynamics makes minimal use of both formal data and the traditional theories of social science. It has relied heavily on perceptive insight and bold assertion, conditioned by time series data only insofar as they have been absorbed by the modeler. The system dynamicist chooses variables and equations because of their believed behavioral significance, not on the basis of whether reliable data exist. Attention is focused on structuring the causal relationships underlying system behavior, rather than developing extensive empirical data. By emphasizing the internal mechanisms that produce change, a better understanding of system behavior can be gained.

The development of credible general aviation activity forecasts has been severely hindered by the lack of extensive data for describing behavior within the general aviation system. Most present forecasting tools use econometric techniques which rely heavily on statistical estimation of relevant parameters. As a result of the data limitations, these methods have fallen short of the desired results.

Econometrics attempts to establish quantitative relationships between economic variables with the aid of statistical methods (7). It is important to distinguish between two realms of econometrics: economic theory and econometric methods. Economic theory is concerned with the relationships between economic variables. Theory formulates, for example, hypotheses about how consumers will react to price changes. The methods of econometrics are basically those of regression analysis. In particular, the econometrician applies these methods together with a priori information and observed data to make inferences about unknown parameters. Zellner (8) has indicated the following as a few of the many estimation principles in econometrics: maximum likelihood, least squares, best linear unbiased estimation, generalized least squares, minimum absolute deviations, minimum chi-square, indirect least squares, instrumental variable methods, generalized classical linear estimations,

two and three stage least squares, simultaneous equation least squares, etc. Many are not generally applicable.

Economic theory provides a priori relationships between important system variables. However, these are not laws of nature, and as a result, their formulation must recognize the inclusion of random error terms. Estimation of the unknown parameters proceeds from normal regression analysis of empirical data. These data can be either time series or cross-sectional. A usual assumption is that the form of the structural equation will be unchanged in the sample and postsample period. Occasionally, econometric models will include time as a variable to indicate changes in structure; but the dependence on observable data is still apparent. Other complications can arise when the model is comprised of a set of simultaneous equations. The basic steps to be followed in the development of an econometric model are: choose the relevant variables, obtain suitable data, choose functional form, statistically estimate the parameters, and interpret results.

It is not that the methods and objectives of econometric analysis are not applicable to the general aviation system, but that the results have been disappointing. The data are definitely deficient, and as a result, recent econometric models of general aviation have been grossly simplified, statistically incorrect, and poorly communicated. The main problem has been improper application of econometric techniques, although the objectives are commendable.

Nevertheless, planning for the future of general aviation cannot wait until adequate data are assimilated. Alternative policy actions need to be formulated now and evaluated with the best information and understanding currently available. Econometrics has been unsuccessful. A new approach is needed. System dynamics (9) could be the answer.

The key to policy modeling is to correctly portray the structural representation of the real system, not only with respect to past conditions but also in anticipation of future conditions. In order to adequately express system behavior, cause-effect relationships must be identified and quantified as structural equations. Two problems arise: first, there may not be adequate empirical data available to construct

significant relationships, in the statistical sense, and second, the scope of the independent variables in a typical socioeconomic system would undoubtedly be surpassed during any projections into the future. Even if an adequate relationship can be defined through the present conditions, how this function is to be extrapolated outside the scope of available empirical data requires serious contemplation.

System dynamic models have been developed based on a recognition of the importance for structural integrity. With respect to modeling the general aviation system, the mathematical rigor of econmetric methods is certainly desirable. However, much of the knowledge and information concerning the attitudes within general aviation is intuitive, rather than empirical. A better approach to modeling the general aviation system, indeed any social system with potential policy implications, appears to be the application of Kantian principles. Under this philosophy, the system is modeled by simultaneously considering the underlying structure and the data requirements, both empirical and subjective. Thus, for example, based on an awareness of the available empirical data and an intuitive feel for internal behavior, a more realistic structural model of the general aviation system could be developed.

System dynamics provides useful inputs to the policy evaluation process by improving understanding of system behavior, by being able to design alternative policies, and by evaluating policy options. In contrast to simply forecasting future events, system dynamics attempts to identify the underlying structure in order to be able to control the future. Sensitivity tests applied to system dynamic models can indicate critical areas where policy implementation is likely to be most effective.

There are many approaches to modeling complex systems. Some concentrate on explaining past behavior, others concentrate on predicting future conditions. System dynamics should be considered for more ambitious applications where the objective is to control the evolution of the system. It can be a useful tool in analyzing system behavior, designing practical policy options, and evaluating their short-and long-term impacts.

BACKGROUND

Development of the General Aviation Dynamics (GAD) model is the result of a series of research programs conducted by Battelle's Columbus Laboratories. Past studies concentrated on developing a consistent database and methodology for determining the cost elasticity on both the general aviation fleet size and the annual hours flown. However, the inability of the resultant elasticities to adequately explain general aviation behavior during the turbulent mid-70's, suggested that a different approach was needed to describe the complex nature of the general aviation system.

The GAD model is a dynamic simulation model built upon the causal interactions displayed between the various sectors of the general aviation system; viz., the aircraft utilization sector. Implemented in NUCLEUS, a computer-based dynamic simulation and modeling system developed at Battelle, the GAD model is available on-line and is easily accessed through its extensive conversational dialogue.

This report is a comprehensive treatment of the model development efforts which have been completed to date. GAD model was first conceived and formulated under Contract No. DOT-FA 74WA-3485. A four volume report was published which described the model development effort, the data used, and a user's guide to "running" the GAD model:

General Aviation Dynamics
An Extension of the Cost Impact Study
to Include Dynamic Interactions in the
Forecasting of General Aviation Activity
Report No. FAA-AVP-77-20
April, 1977

This initial work was based on actual general aviation activity data through CY 1974.

The current contract (Contract No. DOT-FA77WA-4043) originally called for forecast comparisons and model update based on actual general aviation activity during 1975 only. However, since the 1976 data were available during the conduct of this program, these additional data were included in the analyses. Furthermore, as a result of comments received

from the FAA's review of the Interim Report, it was decided to modify the scope of this contract such that a single comprehensive technical document would be produced, covering the model development efforts within both Contract No. DOT-FA74WA-3485 and Contract No. DOT-FA77WA-4043.

Definitions

Present FAA forecasting methods use a "top-down" approach for projecting general aviation activity; that is, an aggregate level for total GA activity is forecast and, subsequently, subdivided into various sectors of interest. The method presented here is a "bottom-up" approach providing distinct behavioral relationship for each significant user category/aircraft type subsegment.

Seven distinct user categories and seven different aircraft types were chosen for detailed analyses. Of the 49 different possible combinations, only 29 user category/aircraft type subsegments have had a significant amount of activity. Any activity appearing in the other 20 subsegments was included in their nearest related significant subsegment. Table 2 provides definitions of the user categories, aircraft types, and the significant subsegments.

During previous studies, major general aviation cost centers were defined for both the variable cost of aircraft operation and the fixed cost of aircraft ownership. These cost centers are defined in Table 3. Whenever general aviation costs are used in the GAD model, the cost in current dollars is first converted to constant 1972 values and then indexed to the 1972 corresponding value. This technique is useful in analyzing changes in real costs, after adjusting for inflation.

General Aviation Activity Survey

On August 23 and 26, 1975, the Federal Aviation Administration and the Civil Air Patrol conducted a survey of general aviation activity at 71 towered airports and 174 nontowered airports throughout the United States and Puerto Rico. During the two-day survey, 35,000 aircraft

TABLE 2. SIGNIFICANT GENERAL AVIATION SUBSEGMENTS

User Category I \ Aircraft Type J	1	2	3	4	5	6	7
1		X		X	X		X
2		X				X	
3		X		X	X		X
4	X			X	X		X
5		X		X	X		X
6		X					
7		X					

User Categories

1. Business Transportation
2. Corporate Transportation
3. Personal Flying
4. Aerial Application
5. Instructional Flying
6. Air Taxi
7. Other

X - Denotes insignificant activity

Aircraft Types

1. Single-Engine Nonaerial
2. Single-Engine Aerial
3. Multiengine Piston
4. Turboprop
5. Turbojet
6. Piston-Engine Helicopter
7. Turbine-Engine Helicopter

TABLE 3. COST CENTER DEFINITIONS

FUEL AND OIL COSTS ($/HOUR)

Fuel and oil cost per hour are based on the average consumption rate at 75 percent power. Airframe and engine manufacturers recommended fuel type were used for all calculations. The Fuel and Oil Cost Center includes state and federal fuel tax.

AIRFRAME AND AVIONICS MAINTENANCE AND OVERHAUL COST ($/HOUR)

This cost center includes all labor and parts costs associated with scheduled and unscheduled airframe and avionics maintenance and overhaul.

ENGINE MAINTENANCE AND OVERHAUL ($/HOUR)

Engine maintenance and overhaul includes costs for scheduled and unscheduled engine maintenance, overhaul, 100 hour, 1000 hour, and/or annual inspections. Includes also midpoint and cycle costs for turbine engines.

ANNUALIZED INVESTMENT ($/YEAR)

The purpose of the annualized investment cost center is to represent an annual dollar amount for ownership cost of the aircraft itself. A straight line annualizing schedule applied to the aircraft's first year retail price, including sales tax, has been used.

HULL INSURANCE ($/YEAR)

Hull insurance cost is the annual premium paid to insure the aircraft against damage while in motion or at rest. A deductible amount is normally included.

LIABILITY AND MEDICAL INSURANCE ($/YEAR)

Liability insurance premiums are paid to insure the aircraft owner against damage to persons or property by reason of his operation of the aircraft.

HANGAR, STORAGE AND TIE DOWN ($/YEAR)

Hangar, storage and tie down rates are averaged from known regional hangar rates, parking fees, and manufacturer suggested rates.

TABLE 3. COST CENTER DEFINITIONS (Continued)

FEDERAL REGISTRATION FEE AND WEIGHT TAX ($/YEAR)	The Federal registration fee and weight tax went into effect July 1, 1970. The rates are: • Reciprocating powered aircraft - $25 plus $0.02 per pound for aircraft of gross weight over 2,500 pounds. • Turbine powered aircraft - $25 plus 0.035 per pound of gross weight
MISCELLANEOUS ($/YEAR)	Miscellaneous costs include allowance for the state aircraft registration fees, training, catering, landing fees, navigation materials, airworthiness directive requirements and minor modifications.

operations were recorded while interviewing 7,800 pilots. Statistical results of the survey data have been reported by the FAA.

Results of a similar survey which had been conducted in 1972 were used in determining operations by each user category and included in the original General Aviation Dynamics model. The more recent survey results provide better and more extensive data for estimating general aviation aircraft operations.

The GAD model is based on describing individual behavior within 7 different user categories of general aviation for 7 different aircraft types. It assumes that, when converting annual hours flown to numbers of various type operations, the flight characteristics within any one of 29 significant subsegments will remain constant over time. For example, the average trip time within the personal/multi-engine piston subsegment is not expected to change radically from year to year, nor is the percentage of local versus itinerant flights within the corporate/turbojet subsegment. By distinguishing individual flight characteristics within each subsegment, the credibility of forecasts for operations will be preserved even as the aircraft mix changes within user categories.

The 1975 survey data were used to estimate total, local, and itinerant operations per flight hour for each of the 29 subsegments (Table 4). Annual operations can be estimated by multiplying each of these values times the corresponding estimated annual hours flown. This procedure indicated a grand total of 104 million operations during 1975 which, being a reasonable estimate, justified using this method in the GAD model.

The survey data were also used to estimate the number of IFR flight plans per flight (a flight equals two operations). These values were used to estimate the total number of IFR flight plans filed during 1975. Estimated values differed by only one percent from the FAA-reported figures.

Subsequent chapters in this volume provide a detailed discussion of the development of the GAD model and an example of using the model for policy evaluation.

Local Operations Per Flight Hour

Aircraft Type J

User Category I	1	2	3	4	5	6	7
1	0.78	X	0.38	X	X	1.29	X
2	0.65	X	0.06	0.05	0.02	X	0.19
3	2.28	X	0.91	X	X	4.42	X
4	X	1.60	0	X	X	4.32	X
5	5.21	X	4.23	X	X	15.86	X
6	0.70	X	0.16	0.08	0	0.16	0.16
7	2.36	X	2.04	1.84	0	2.72	2.72

Itinerant Operations Per Flight Hour

Aircraft Type J

User Category I	1	2	3	4	5	6	7
1	1.37	X	1.49	X	X	1.18	X
2	1.16	X	1.69	1.40	1.60	X	3.03
3	0.92	X	1.11	X	X	0.82	X
4	X	0.81	0.72	X	X	0.54	X
5	0.50	X	0.40	X	X	0.17	X
6	1.68	X	1.90	3.10	1.39	2.12	2.12
7	0.79	X	0.72	1.30	1.91	0.35	0.35

Total Operations Per Flight Hour

User Category I	1	2	3	4	5	6	7
1	2.15	X	1.87	X	X	2.47	X
2	1.81	X	1.75	1.45	1.62	X	3.22
3	3.20	X	2.02	X	X	5.24	X
4	X	2.41	0.72	X	X	4.86	X
5	5.71	X	4.63	X	X	16.03	X
6	2.38	X	2.06	3.18	1.39	2.28	2.28
7	3.15	X	2.76	3.14	1.91	3.07	3.07

User Categories

1. Business Transportation
2. Corporate Transportation
3. Personal Flying
4. Aerial Application
5. Instructional Flying
6. Air Taxi
7. Other

X - Denotes insignificant activity

Aircraft Types

1. Single-Engine Nonaerial
2. Single-Engine Aerial
3. Multiengine Piston
4. Turboprop
5. Turbojet
6. Piston-Engine Helicopter
7. Turbine-Engine Helicopter

TABLE 4. ESTIMATED OPERATIONS PER FLIGHT HOUR

CHAPTER 2. AN OVERVIEW OF THE MODEL

The purpose of this chapter is to give the reader a brief overview of the entire General Aviation Dynamics model before the details of each individual sector are presented. There are three major sectors representing the most important state variables in the model: pilot supply, aircraft demand, and aircraft utilization. The interactions between these sectors form the basis for developing a better understanding of the general aviation system - an understanding which can lead to more formative policy making.

STRUCTURE OF THE GENERAL AVIATION SYSTEM

The first step in modeling the general aviation system is to choose a system boundary that defines the concepts which interact to produce the behavior of interest. Interest here is in the mechanisms that foster the growth of general aviation activity. The system must be thoroughly understood before policies can be designed with the hope of controlling it. Yet the model cannot pretend to predict unforeseen circumstances which might greatly alter the normal system behavior. It should be able to answer "what if" questions concerning its environment. The general aviation model developed herein is representative of the aggregate level of activity within the United States. It has not been constructed for the purpose of evaluating activity on a regional basis; although it should be adaptable to regional studies.

Three levels (state variables) were chosen as the cornerstones on which to build the system structure: aircraft, annual hours, and pilots. Each of these levels represents the principal variable in a major sector of the general aviation system. The three levels interact in multiple ways, as indicated on the flow diagram of the entire system structure in Figure 1.

System dynamics flow diagram symbols are summarized in Figure 2. The system levels appear as rectangles. Note that the active aircraft level is subscripted I,J on Figure 1. This is to indicate that

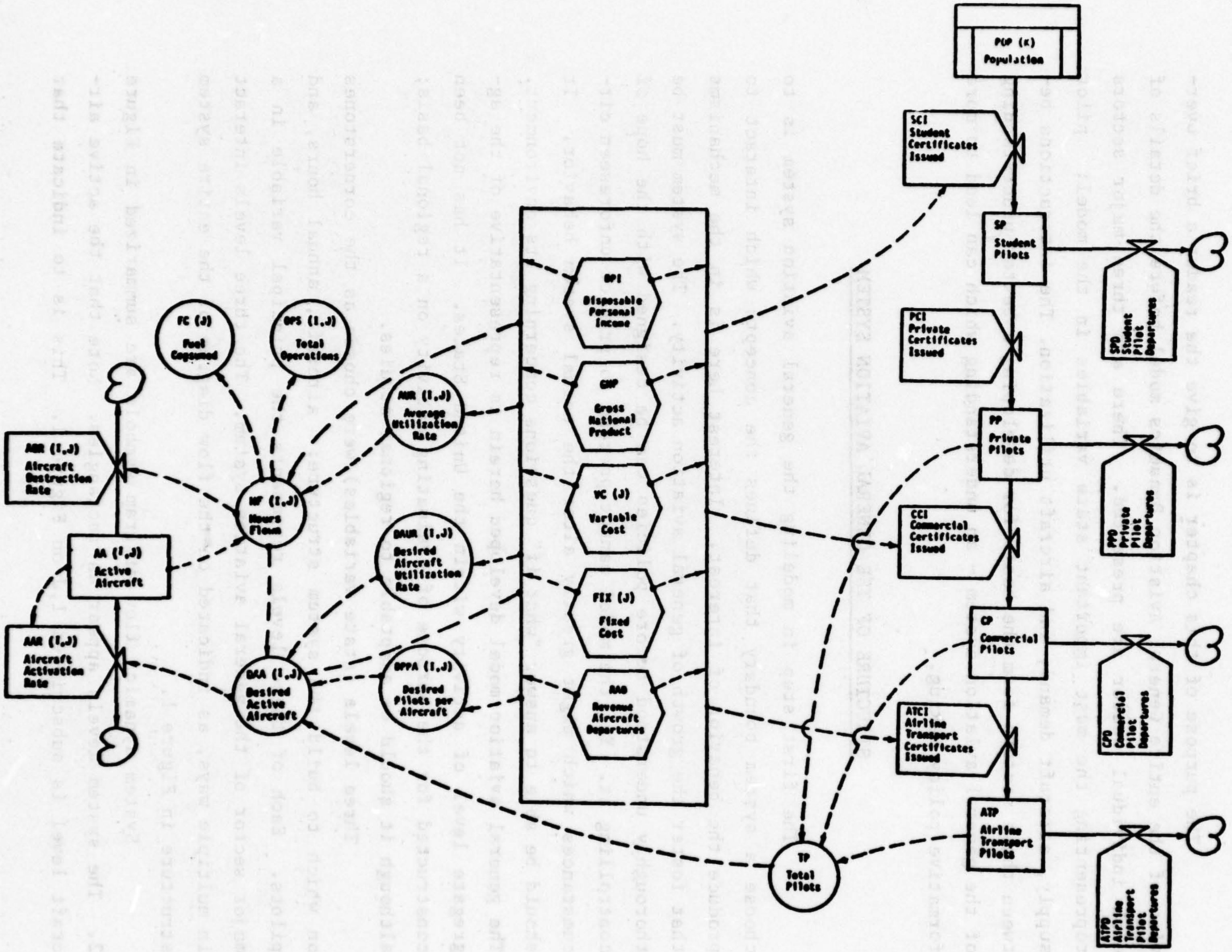

FIGURE 1. GENERAL AVIATION DYNAMICS FLOW DIAGRAM

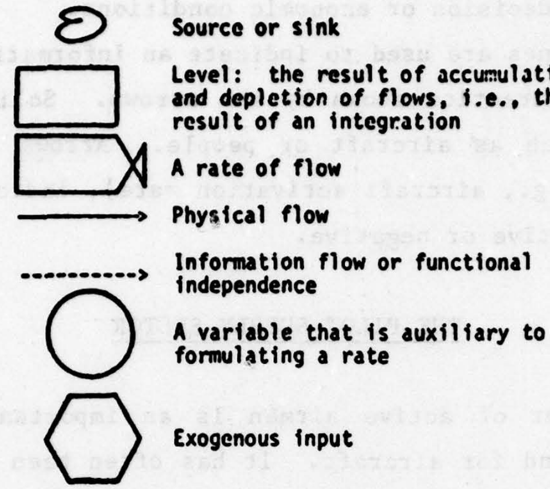

FIGURE 2. SYSTEM DYNAMICS FLOW DIAGRAM SYMBOLS

active aircraft are distinguished by the number of aircraft of type J (J = 1,2,...7) within user category I (I = 1,2,...7).

Rates are the systems's action or policy variables which effect changes in the levels. Aircraft activation and destruction rates control general aviation activity. Airman certificate issuances and departure rates determine the active pilot population.

Since the rates acting on a level summarize the effects of all factors which influence the state of that level, they are generally complex expressions. Often, one or more components of a rate are sufficiently important to warrant individual attention. These auxiliary variables are separated algebraically from the rate equation. One such auxiliary variable is the desired-active-aircraft parameter, which represents the goal that each subsegment is striving to achieve under the present system conditions.

The exogenous inputs provide a direct means for the policy maker to evaluate various fiscal policies and "what if" situations. Implemented in NUCLEUS, a computer software system developed at Battelle, an interactive dialogue feature allows the analyst to easily

modify these exogenous variables in order to examine the ramifications of various policy decision or economic conditions.

Dotted lines are used to indicate an information flow or causal influence in the direction shown by the arrows. Solid lines represent physical flows such as aircraft or people. Arrows located on either side of a rate (e.g., aircraft activation rate), indicate that the rate can be either positive or negative.

THE PILOT SUPPLY SECTOR

The number of active airmen is an important element in determining the demand for aircraft. It has often been said that "pilots buy airplanes". This is especially true for those aircraft owned and operated by the same individual; typically, these are business and personal use aircraft. The pilot supply sector develops projections of the active pilot population by type of certificate and also the number of both instrument and helicopter ratings.

The controlling factor in determining ultimate pilot population is the rate of student certificate issuances. By dividing the U.S. population over 16 years old into three distinct age groups, recent data can be used to show a definite relationship between student certificates issued, population, relative cost of flying, and individual affluence.

A valid description of the pilot supply sector must recognize the required progression of steps necessary to qualify for advanced certificates. The inherent delays encountered in satisfying these requirements are an important part of the model definition. It is these delays that explain the continued growth in numbers of active pilots during times of reduced student issuances. The importance of the way in which progression takes place within the pilot supply sector is stressed here because most present pilot forecasting methods try to forecast the active number of different pilot types independently. Since pilot upgrading and departing occurs continuously over time, this system dynamic approach should provide a better understanding of the true behavior within the pilot sector.

THE AIRCRAFT DEMAND SECTOR

The structure of the aircraft demand sector is identical for all subsegments of general aviation. Each subsegment has its own goal for a desired number of active aircraft which it is striving to achieve. The main difference between subsegments is in the functional expression for their respective goals. The primary demand may be for the aircraft itself or only for the service provided by the aircraft.

The demand for aircraft that are owned and operated by the same individual (viz, business and personal use categories) is a primary demand which is likely to be dependent on the supply of such individuals. These are, of course, the number of active certified pilots. As the number of active pilots increases, the demand for active (business and personal) aircraft will increase. This concept is expressed through the desired-pilots-per-aircraft ratio. However, in certain cases, the desired-pilots-per-aircraft parameter is shown to be a function of price and general economic conditions. Thus, it will be shown that as the relative economic attractiveness of owning an aircraft goes down, the same number of pilots will demand fewer aircraft.

Consider the demand for aircraft that are used in providing a service (viz, aerial application, instructional, air taxi, and rental). Here the primary demand is for the service provided. Aircraft demand is secondary and is dependent on the extent that these aircraft are presently being used. Should the average annual utilization rate of a particular aircraft type within one of these user categories surpass some threshold, then there will be a need for additional aircraft to satisfy what may be an excess demand. The goal for desired number of active aircraft is related to the ratio of a desired aircraft utilization rate and an actual aircraft utilization rate.

Demand for corporate aircraft is different yet. It is true that corporate aircraft are usually owned and operated by the same corporation, but there are no indications that companies cannot hire the pilots required to fly these aircraft. Thus the demand for corporate aircraft is based on a desired number of aircraft which is directly related to general economic conditions. Intuitively, this functional

dependence is appealing. For, should real economic growth be stagnated causing real GNP to remain constant, the desired number of corporate aircraft would also remain constant. Ultimately, the demand for additional corporate aircraft would represent only replacement of destroyed aircraft. However, if the economy continues to grow, an ever increasing number of active corporate aircraft will be desired.

THE AIRCRAFT UTILIZATION SECTOR

Several different behavioral subsegments are evident within the aircraft utilization sector. First is the owner-operator situation, characterized by the business and personal use categories. Here an aircraft is purchased and operated by the same individual. The average annual utilization rate for these aircraft has been varying about a nominal value. Thus, total annual utilization by each subsegment is obtained by taking the product of active aircraft and average annual utilization rate.

Demand for aerial application, instructional, and air taxi flying represents an aggregate demand for a general aviation service. The total annual hours demanded are distributed among the available aircraft to determine a derived annual utilization rate. These derived utilization rates are used in determining the demand for additional aircraft in these categories.

Behavior of the single- and multi-engine piston aircraft owners within the "other" user category, which are predominantly rental operations, is similar to the total hours flown approach. The remaining segments of the "other" use category are based on average utilization rates.

Different user category/aircraft type subsegments respond to different stimuli. Utilization, either average rate or total hours, has shown a significant correlation with variable cost of operation in only a few of the 29 subsegments. Some subsegments have indicated utilizations dependent on GNP, DPI, or the level of commercial air activity. However, the form of these dependencies is, in some cases, opposite the a priori expectation.

The forecasted level of annual hours flown is used to determine the corresponding level of operations within each subsegment. Operations are distinguished by local-itinerant. Annual hours flown is also used in calculating the amount of both piston and jet fuel consumed.

THE DYNAMICS OF AIRCRAFT DEMAND

Although the structure of the aircraft demand sector is identical for all subsegments of general aviation, because of the various uses of general aviation aircraft, the desired stock of active aircraft is determined differently for different users. At any point in time, each subsegment has both an actual number of active aircraft and a desired number of active aircraft which it is striving to achieve. This desired stock can be greater than, less than, or equal to the actual number of active aircraft, depending upon other conditions within the system. Of special interest in explaining fluctuations in aircraft activation is the role of pilot population, average aircraft utilization rates, and exogenous economic parameters.

The demand for aircraft is a derived demand, the primary demand being for transport services provided by the aircraft. This derived demand is demand for a stock (or goal) of aircraft, not for the flow of aircraft activations. The goal, desired-active-aircraft (DAA), can be a complex function of the number of pilots, the average aircraft utilization rate last year, fixed costs, variable costs, and exogenous inputs for Gross National Product (GNP) or Disposable Personal Income Per Capita (DPI). For any particular subsegment, if the stock of aircraft desired is greater than the current number of active aircraft within that subsegment, then additional aircraft will be activated; otherwise, aircraft would be deactivated. Thus, the dynamics within the general aviation system are the result of continuous causal interactions between the pilot supply sector, the aircraft utilization sector, and the aircraft demand sector.

Figure 3 illustrates a portion of the structure that is common to all user categories. The number of active aircraft within any user category/aircraft type subsegment is determined by the aircraft destruction rate and the aircraft activation rate. Although the aircraft

aircraft activation rate can be either positive or negative. The aircraft destruction rate is itself a function of the level of annual hours

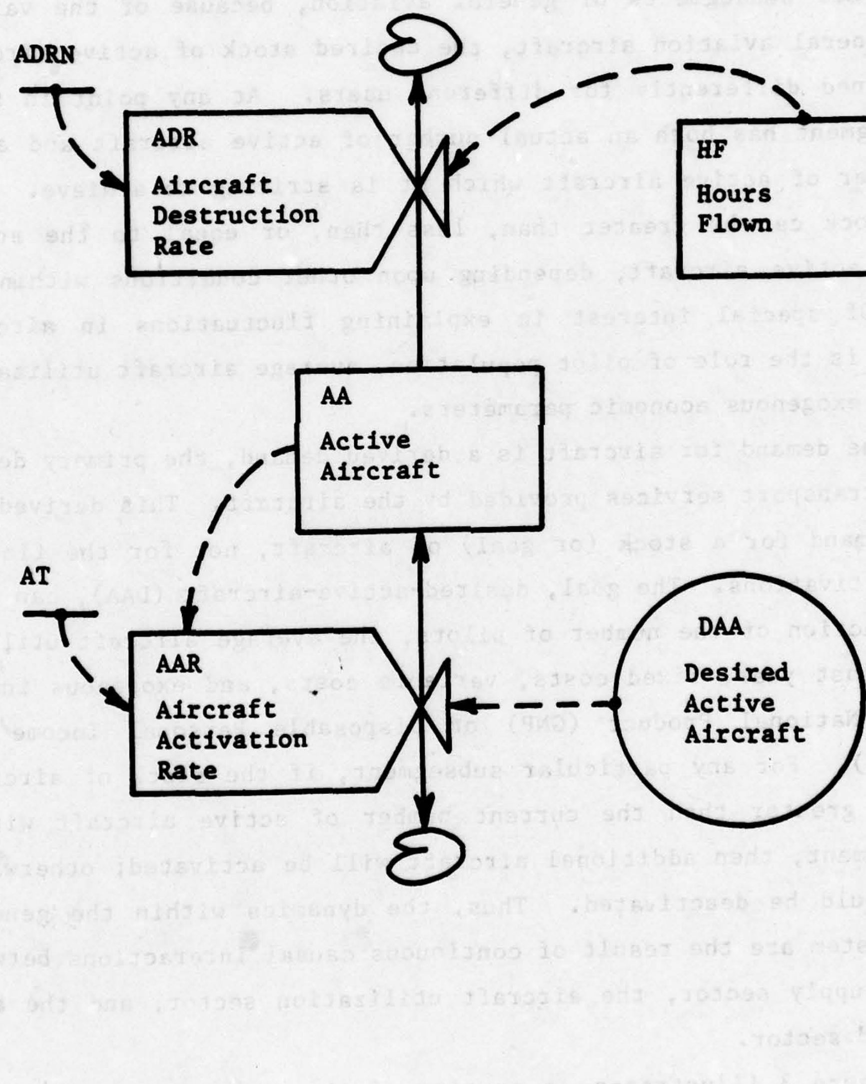

FIGURE 3. THE STRUCTURE OF AIRCRAFT DEMAND

flown - the more general aviation activity, the more aircraft can be expected to be destroyed. Aircraft activation rate represents the combined effect of purchases of new or used aircraft, aircraft deactivations, and aircraft transfers to different user categories. The goal of this system is to maintain the number of active aircraft at the level of desired-active-aircraft.

The following relationship for active aircraft AA(I,J) is a typical level equation which is common to all user categories,

$$AA(I,J)_t = AA(I,J)_{t-1} + DT * (AAR(I,J) - ADR(I,J))$$

$AA(I,J)_t$: active aircraft at time t (aircraft)
AAR(I,J) : aircraft activation rate (aircraft/year)
ADR(I,J) : aircraft destruction rate (aircraft/year)
DT : time interval (years)

This equation is simply a straightforward accounting relationship stating that the present number of active aircraft will equal the previously computed value plus the difference between aircraft activated and aircraft destroyed during the last time interval. Each of the two rates are assumed to be constant during the time interval DT. Throughout the model's equations, DT has been set equal to one year. This was deemed necessary because of the FAA's system for reporting data on an annual basis.

Level equations are simple and noncontroversial. However, rate equations are not so obvious and straightforward. It is in the rate equations that the decision mechanisms of t . system are expressed. These decisions must be formulated so that they remain plausible and intuitively correct over the extreme ranges that may be encountered in the shifting values of the system variables. Rate equations must be developed by carefully considering all those circumstances that might affect system behavior. Very simply, a rate equation is a statement of how action is to be based on a discrepancy between the system's goal and its present condition. Functionally, the aircraft activation rate is expressed as

$$AAR(I,J) = \frac{DAA(I,J) - AA(I,J)}{AT(I,J)}$$

DAA(I,J): desired active aircraft (aircraft)

AT(I,J) : adjustment time (years)

In this equation, the goal is the desired active aircraft DAA(I,J), the observed condition is active aircraft AA(I,J), and the discrepancy between desired and actual conditions is expressed as the simple difference (DAA(I,J) - AA(I,J)). The action to be taken is to activate 1/AT(I,J) of the discrepancy. Thus, should AT(I,J) equal one year, then the entire discrepancy would be eliminated in one year; if AT(I,J) equals two years, only half the discrepancy would be eliminated. Since the aircraft activation rate includes all aircraft transactions, not just new aircraft purchases, the adjustment time does not have to be limited by the expected delay in filling new aircraft orders.

The desired active aircraft, which can be thought of as the "ideal" level of active aircraft under present conditions, is an important concept in formulating the equations within each user category. This goal can be a complex function of the number of active pilots, the average aircraft utilization rates, general economic conditions, or the cost of owning and operating aircraft. It is the determination of valid quantitative relationships for the particular goal of each of the 29 different subsegments of general aviation upon which the credibility of this model lies.

MODEL OUTPUT

The General Aviation Dynamics (GAD) model can be used to forecast (or compare) active aircraft, annual hours flown, and total operations for each of the 29 user category/aircraft type subsegments identified in Table 2. Other forecasts that can be obtained are as follows:

- Active Airmen

  Student Certificates Outstanding

  Private Certificates Outstanding

Commercial Certificates Outstanding

Airline Transport Certificate Outstanding

Helicopter Certificates Outstanding

Instrument Ratings Outstanding

Helicopter Ratings Outstanding

- Annual Fuel Consumption

Aviation Gas

Jet Fuel

- Total Airport Operations (towered plus nontowered)

Itinerant

Local

- GA Contributions to the Federal Trust Fund

In addition to tabular output, most model variables can be plotted either versus time or versus another variable.

This chapter has provided some insight into the structure of the over-all model. The two following chapters describe the model sectors in more detail and outline the manner in which many of the specific formulations were derived.

CHAPTER 3. THE PILOT SUPPLY SECTOR

There are four classes of certificated pilots which are of major importance to general aviation. In order of the required steps for progression these are holders of student, private, commercial, and airline transport certificates. Helicopter pilots are also important in determining the demand for active helicopters. Although not separate certificates, the number of instrument ratings outstanding are an important barometer for measuring future demand on FAA facilities.

To obtain a student certificate, an applicant must be at least sixteen years of age and must have passed an FAA-approved medical examination within the previous two years. Thereafter, medical examinations are required biennially to maintain the validity of the license.

The biennial medical review continues to be necessary after obtaining the private pilot's license, which in turn also requires the pilot to be at least seventeen years of age, to have passed the necessary proficiency tests, and to have had at least 35 hours of flying experience.

To obtain a commercial license, the private pilot must be at least eighteen years old and must have demonstrated a higher level of proficiency in both written and flight examinations. The commercial pilot must have had at least 250 hours of flying time, including a specified proportion of instructional and other experience. Medical examinations for commercial pilots are required annually.

An airline transport pilot must be at least 23 years of age and is required to have a medical examination semiannually.

The progression of pilots through ever-increasing levels of proficiency, and their departures from the system altogether, suggests characterization as a classical birth-death process. Prior to conceptualizing the pilot supply sector, it is essential to define the purpose of this sector. First, it should provide a thorough understanding of the pilot upgrade process. It should identify the source of potential pilots, recognize the differences between age groups, and capture the relative price concept. There should be enough detail so that

it will be possible to analyze abnormal future behavior. Second, the pilot supply sector must provide the necessary information to be used in other parts of the model, especially the aircraft demand process. Pilot training should also be consistent with the level of instructional flying within the aircraft utilization sector.

Each active airman type is represented by a level variable which can be increased by the rate of new issuances, decreased by the rate of upgrade to the next level, and decreased by the rate of dropouts. It is the identification of these rates that is the crux of the problem. All of the data used in quantifying these relationships have been obtained from various issues of the FAA Statistical Handbook of Aviation.

Student Pilots (SP)

Student pilots in Figure 4 is a system "level" variable. The active number of student pilots at any point in time is calculated as the student pilot population at the preceding point in time, plus the number of student certificates issued during the intervening interval, minus the number of private certificates issued, minus the student dropouts. Mathematically this is expressed as

$$SP_t = SP_{t-1} + DT(SCI - PCI - SPD)$$

SP_t: Student pilots at time t (people)
DT: Time interval, DT = (t) - (t-1) (years)
SCI: Rate of student certificate issuances (people/year)
PCI: Rate of private certificate issuances (people/year)
SPD: Rate of student pilot departures (people/year)

Student Certificates Issued (SCI)

Figure 5 is a plot of the student certificates issued during each year since 1964. The mid-60s experienced a tremendous growth in the number of certificates issued annually. Through the late-60s and

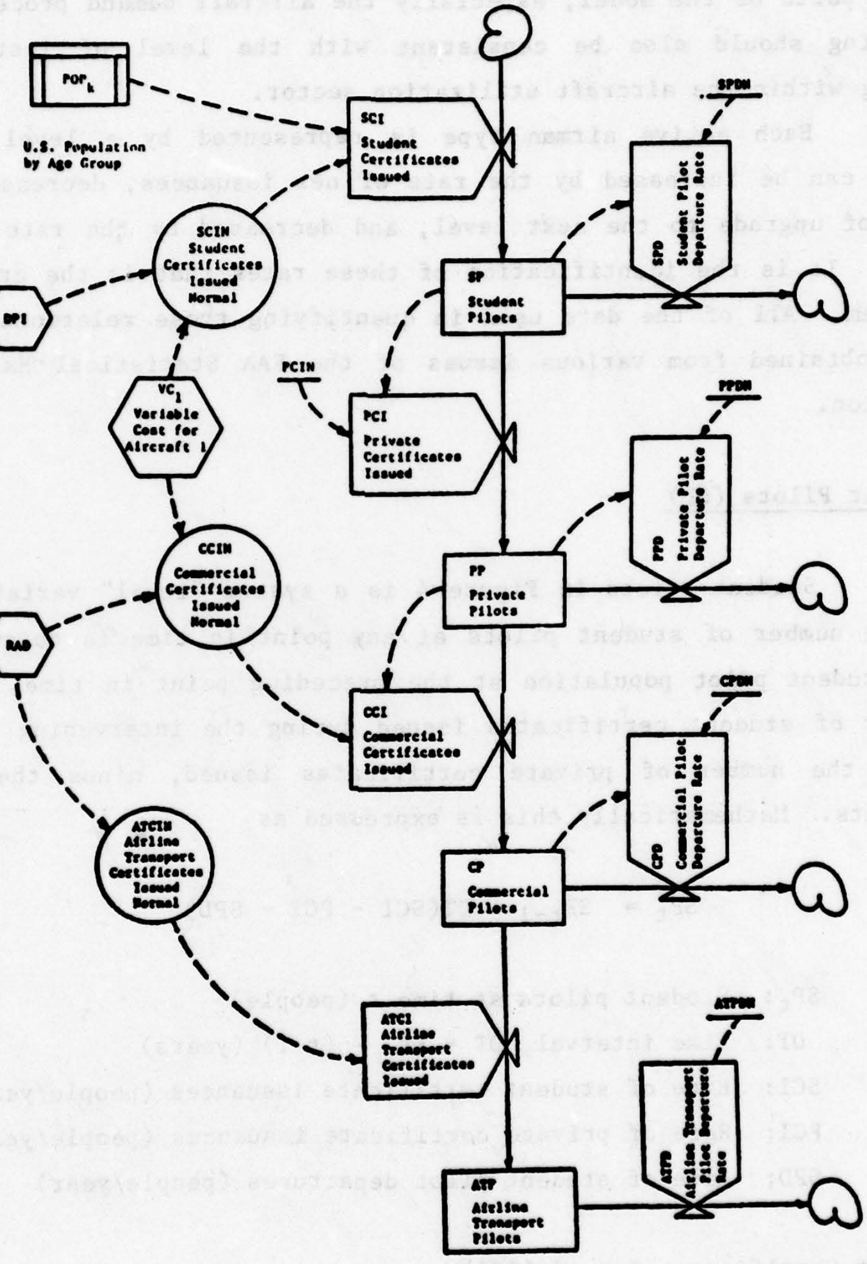

FIGURE 4. PILOT SUPPLY SECTOR

into the 70s, the number of certificates issued decreased and essentially leveled out.

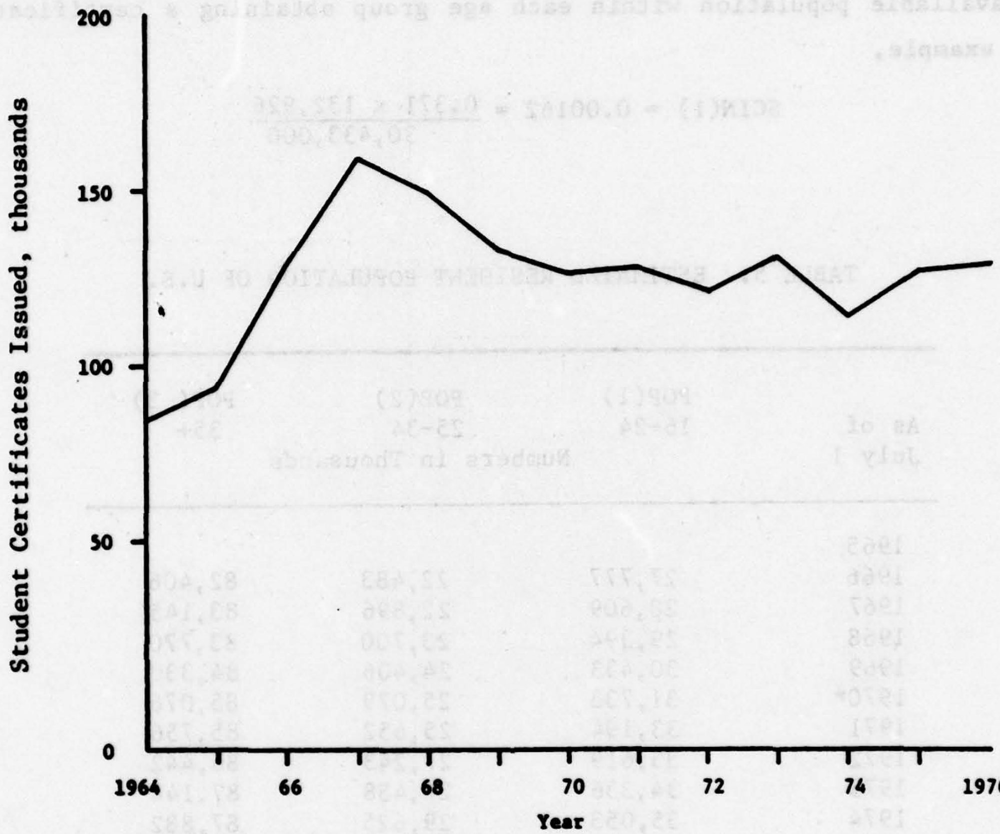

FIGURE 5. STUDENT CERTIFICATES ISSUED ANNUALLY

This phenomena may be explained by noting that the general aviation pilot boom of the mid-60s was the result of persons in all age groups obtaining initial certification. As time progressed these older age groups became saturated, to the extent that most persons in an older age group who desired to become a pilot would already have done so. Thus, for the most part, student certificates issued now are to persons just becoming of available age or financially able.

The estimated resident population of the U.S. is presented in Table 5 for each of three age groups over the past ten years. Table 6

presents data on the fraction of student certificates held by members of these three age groups as of January 1, 1970-1977, the total number of student certificates issued during the previous year, and the fraction of available population within each age group obtaining a certificate. For example,

$$SCIN(1) = 0.00162 = \frac{0.371 \times 132,926}{30,433,000}$$

TABLE 5. ESTIMATED RESIDENT POPULATION OF U.S.

As of July 1	POP(1) 16-24	POP(2) 25-34	POP(3) 35+
	Numbers in Thousands		
1965			
1966	27,777	22,483	82,406
1967	28,609	22,896	83,145
1968	29,394	23,700	83,770
1969	30,433	24,406	84,330
1970*	31,733	25,079	85,076
1971	33,194	25,652	85,756
1972	33,619	27,243	86,442
1973	34,336	28,458	87,144
1974	35,053	29,625	87,882
1975	35,778	30,783	88,703
1976	35,982	31,353	88,825
1977	36,173	31,803	88,895

Source: U.S. Bureau of the Census, Current Population Reports, Series p-25, No. 519. "Estimates of the Population of the United States by Age, Sex, and Race: April 1, 1960, to July 1, 1973", U.S. Government Printing Office, Washington, D.C., 1974.

The issuance of student certificates is most likely a relatively stable situation now that the initial boom period has passed. Therefore, the rate of issuance should be related to the level of

TABLE 6. STUDENT CERTIFICATES BY AGE GROUP

As of Jan.1	Fraction of Student Cert. in Each Age Group 16-24	25-34	35+	Student Cert. Issued Previous Year	SCIN(1) Fraction of Available Population Obtaining A Student Cert. Previous Yr. 16-24	SCIN(2) 25-34	SCIN(3) 35+
1970	.371	.347	.282	132,926	.00162	.00190	.000444
1971	.384	.333	.283	126,971	.00154	.00168	.000422
1972	.373	.334	.293	128,004	.00144	.00167	.000437
1973	.364	.337	.299	121,543	.00132	.00150	.000420
1974	.372	.339	.289	131,384	.00142	.00156	.000436
1975	.372	.341	.287	113,997	.00121	.00131	.000372
1976	.364	.343	.292	127,242	.00130	.00142	.000419
1977	.354	.353	.293	129,280	.00127	.00146	.000426

individual affluence and the relative cost of obtaining a private certificate. Specifically, the influence of disposable personal income per capita (DPI) and variable cost of operating single engine piston aircraft [VC(1)] on the rates of issuance were investigated. Since no historical data on the absolute cost of obtaining the various certificates could be found, VC(1) was chosen as a relative indicator for the total cost of obtaining a certificate.

Linear regression equations were developed by first indexing the variable cost (1972 value = 1). Both VC(1) and DPI were included as independent variables in a stepwise linear regression analysis. The most significant results were

$$SCIN(1) = 0.001412 * \underset{(-1.85)}{VC(1)^{-1.294}} \; \underset{(0.23)}{*DPI^{0.208}}$$

$$R^2 = 0.81$$

$$F_{2,5} = 10.6$$

$$SCIN(2) = 0.00158 * \underset{(-1.74)}{VC(1)^{-1.455}} \; \underset{(0.17)}{*DPI^{0.193}}$$

$$R^2 = 0.80$$

$$F_{2,5} = 1.9$$

$$SCIN(3) = 0.000426 * \underset{(-1.65)}{VC(1)^{-1.084}} \; \underset{(1.17)}{*DPI^{1.019}}$$

$$R^2 = 0.43$$

$$F_{2,5} = 1.9$$

The t-statistics associated with each estimated coefficient are contained in parentheses immediately below the corresponding coefficient.

The rate of student certificate issuance is then

$$SCI = \sum_{K=1}^{3} SCIN(K)*POP(K)$$

where POP(K) is the total population within the Kth age group.

Student Pilot Departure Rate (SPD)

Student pilot departure depends on the student pilot population SP and on a normalized coefficient SPDN. Student pilot departure rate normal SPDN states the dropout rate per year as a fraction of the student pilot population. SPD, as defined here, is the total rate at which students are dropping out. It is measured in people per year. Calculated values for SPDN since 1964 are presented in Table 7. Since there appears to be no trend in the data, it was decided to exponentially smooth these data in order to determine the best value to use in forecasting dropout rates beyond 1975. The smoothed value of SPDN is 0.406.

Private Certificates Issued (PCI)

The rate at which private certificates are issued also depends on the student pilot population SP and on a normalized coefficient PCIN. Private certificates issued normal PCIN states the upgrade rate per year as a fraction of the student pilot population. PCI is the total rate at which students are achieving private pilot status. It is measured in people per year. Figure 6 shows that private certificates issued follows the same pattern as student certificates issued. Table 7 also presents annual values for PCIN since 1964. The exponentially smoothed value is PCIN = 0.279, and the rate for private certificates issued is simply

$$PCI = PCIN*SP$$

If the reciprocal of SPDN + PCIN is formed, the result will be the average "life expectancy" of (a student pilot. Substituting in the smoothed values yields an average student pilot lifetime of 1.46 years. This seems entirely reasonable in view of the fact that a student certificate is only valid for two years.

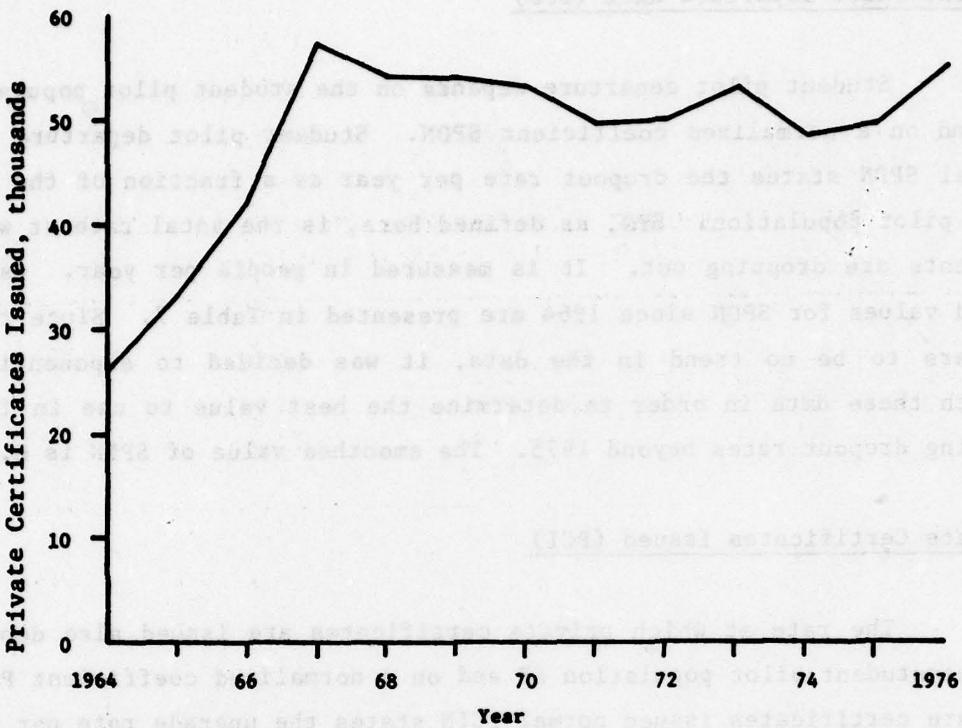

FIGURE 6. PRIVATE CERTIFICATES ISSUED ANNUALLY

Private Pilots (PP)

Private pilots PP at any point in time is calculated as the private pilot population at the preceding point in time, plus the number of private certificates issued during the intervening interval, minus the number of commercial certificates issued, minus the private pilot departures,

$$PP_t = PP_{t-1} + DT(PCI - CCI - PPD)$$

PP_t: Private pilots at time t (people)

CCI: Rate of commercial certificates issued (people/year)

PPD: Rate of private pilot departures (people/year)

TABLE 7. STUDENT PILOT DEPARTURE RATE NORMAL AND PRIVATE CERTIFICATES ISSUED NORMAL

	1. Student Certificates As of Jan. 1	2. Student Certificates Issued During	3. Private Certificates Issued During	4. Student Departures During	(4÷1) SPDN	(3÷1) PCIN
1977	188,801	--	--	--	--	--
1976	176,978	129,280	55,583	61,874	.350	.314
1975	180,795	127,424	49,733	81,508	.451	.275
1974	181,905	113,997	48,501	66,606	.366	.267
1973	181,477	131,384	53,140	77,816	.429	.293
1972	186,428	121,543	50,523	75,971	.408	.271
1971	195,861	128,004	49,579	87,858	.448	.253
1970	203,520	126,871	53,026	81,504	.400	.261
1969	209,406	132,926	54,597	84,215	.402	.261
1968	181,287	149,444	54,232	67,093	.370	.299
1967	165,177	159,399	57,520	85,769	.519	.348
1966	139,172	129,180	42,464	60,711	.436	.305
1965	120,743	94,635	33,337	42,869	.355	.276
1964	105,298	84,629	26,425	42,759	.406	.251

Private Pilot Departure Rate (PPD)

Private pilot departure rate PPD is calculated according to

$$PPD = PPDN * PP$$

where the private pilot departure rate normal (PPDN = 0.076) is an exponentially smoothed average of the annual values presented in Table 8.

Commercial Certificates Issued (CCI)

The rate at which commercial certificates are issued depends on the private pilot population PP and on a normalized coefficient CCIN. Commercial certificates issued normal CCIN states the upgrade rate per year as a fraction of the private pilot population. CCI is the total rate at which private pilots are progressing to commercial pilot status. Historical data for CCI, measured in people per year, is plotted on Figure 7. Table 8 presents annual values for CCIN since 1964. In a manner similar to SCIN(K), the normal rate of issuance for commercial certificates was found to depend on both variable cost and the annual level of revenue aircraft departures by the commercial airlines (RAD),

$$CCIN = 0.0587 * \underset{(-1.64)}{VC(1)^{-2.024}} * \underset{(0.37)}{RAD^{0.837}}$$

$$R^2 = 0.68$$
$$F_{2,5} = 5.4$$

The rate for commercial certificates issued is determined according to

$$CCI = CCIN*PP$$

TABLE 8. PRIVATE PILOT DEPARTURE RATE NORMAL AND COMMERCIAL CERTIFICATES ISSUED NORMAL

	1. Private Certificates As of Jan. 1	2. Private Certificates Issued During	3. Commerical Certificates Issued During	4. Private Pilot Departures During	(4÷1) PPDN	(3÷1) CCIN
1977	309,005	--	--	--	--	--
1976	305,863	55,583	13,577	38,864	.127	.044
1975	305,848	49,733	12,620	37,098	.121	.041
1974	298,921	48,501	17,693	23,881	.080	.059
1973	307,000*	53,140	16,769	?	-	.055
1972	299,000	50,523	16,043	26,480	.088	.054
1971	290,000	49,579	16,356	24,223	.084	.056
1970	286,000	53,026	21,130	27,896	.098	.074
1969	268,000	54,597	21,399	15,198	.057	.080
1968	240,000	54,232	20,157	6,075	.025	.084
1967	209,000	57,520	19,996	6,524	.031	.096
1966	183,000	42,464	14,210	2,254	.012	.078
1965	162,000	33,337	11,043	1,294	.008	.068
1964	139,000	26,425	8,772	?	-	.063

* At the close of 1973, there was a purging of the Airmen Certification files. During this process, approximately 26,000 duplicates or faulty records were eliminated. In order to account for this purging, 16,000 were subtracted from all earlier private pilot totals, 10,000 from commercial, and 26,000 from instrument ratings.

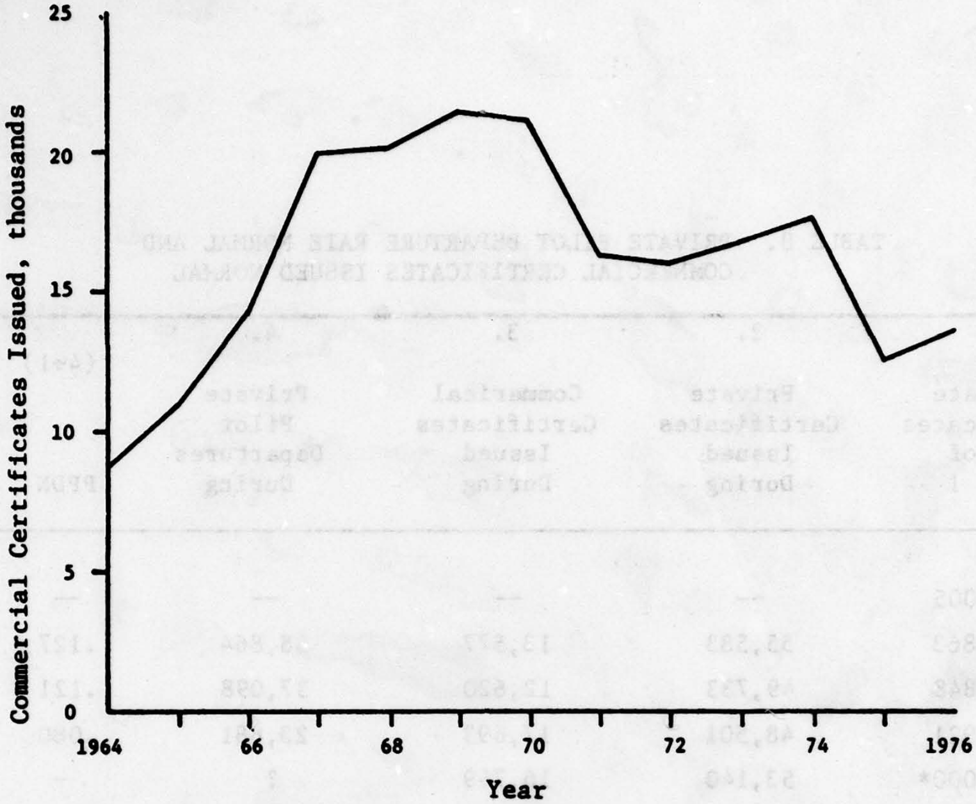

FIGURE 7. COMMERCIAL CERTIFICATES ISSUED ANNUALLY

Commercial Pilots (CP)

Commercial pilots CP at any point in time are calculated as the commercial pilot population at the previous point in time, plus the number of commercial certificates issued during the intervening interval, minus the number of airline transport certificates issued, minus the commercial pilot departures,

$$CP_t = CP_{t-1} + DT(CCI - ATCI - CPD)$$

CP_t: Commercial pilots at time t (people)

ATCI: Rate of airline transport certificates issued (people/year)

CPD: Rate of commercial pilot departures (people/year)

Commercial Pilot Departure Rate (CPD)

Commercial pilot departure rate CPD is calculated according to

$$CPD = CPDN*CP$$

Annual values for CPDN are given in Table 9; the exponentially smoothed value for CPDN is 0.046.

Airline Transport Certificates Issued (ATCI)

The rate at which new airline transport certificates are issued (Figure 8) is expected to be dependent upon the level of commercial airline activity. Since those pilots obtaining these certificates must already hold a commercial certificate, the rate of issuance depends on the active commercial pilot population and on a normalized coefficient ATCIN. Airline transport certificates issued normal defines the fraction of commercial pilots expected to upgrade to airline transport status within any given year. It is through this parameter that the dependence on commercial airline activity must be determined. Table 9 presents annual values for ATCIN since 1968. In regressing these values with annual levels of commercial airline activity, it was decided that the rate of growth of commercial airline activity might best explain the data. The regression results are

$$ATCIN = 0.0183 + \underset{(3.77)}{0.0660} * \frac{\Delta RAD}{RAD}$$

$$R^2 = 0.74$$

$$F_{1,5} = 14.2$$

The absolute airline transport certificates issued rate becomes

$$ATCI = ATCIN*CP$$

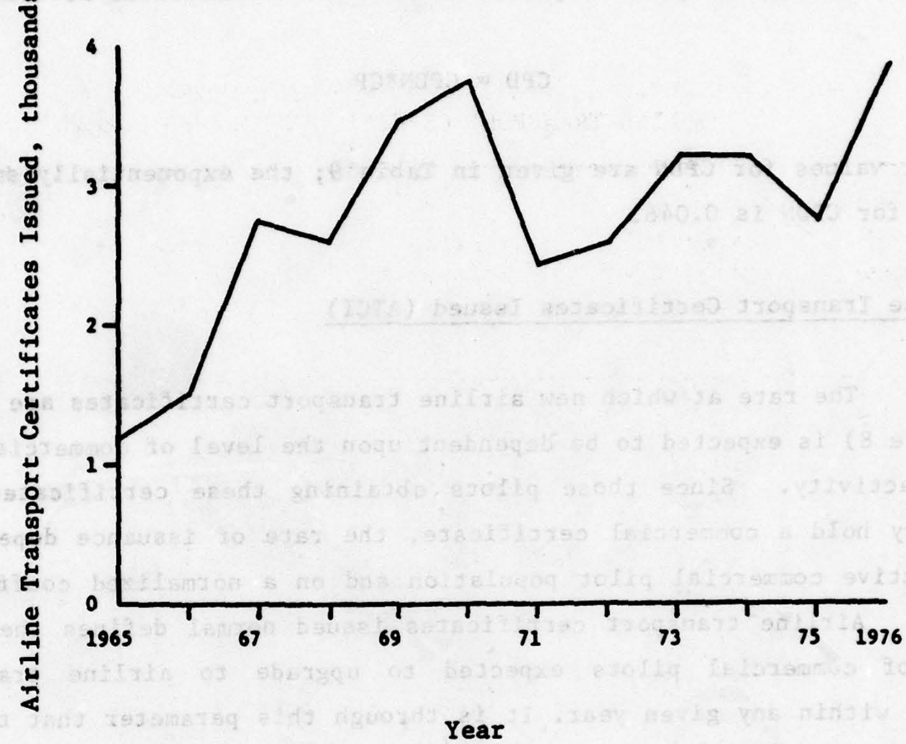

FIGURE 8. AIRLINE TRANSPORT CERTIFICATES ISSUED ANNUALLY

Airline Transport Pilots (ATP)

The active number of airline transport pilots ATP is determined as for each of the other pilot categories, except that there is no higher status for airline transport pilots to achieve. Thus,

$$ATP_t = ATP_{t-1} + DT(ATCI - ATPD)$$

ATP_t: Airline transport pilots at time t (people)

ATPD: Rate of airline transport pilot departures (people/year)

TABLE 9. COMMERCIAL PILOT DEPARTURE RATE NORMAL AND AIRLINE TRANSPORT CERTIFICATES ISSUED NORMAL

	1. Commercial Certificates As of Jan. 1	2. Commercial Certificates Issued During	3. Airline Transport Issued During	4. Commercial Pilot Departures During	(4÷1) CPDN	(3÷1) ATCIN
1977	187,801	--	--	--	--	--
1976	189,342	13,577	3869	11,249	0.0594	0.0204
1975	192,425	12,620	2765	12,938	0.0672	0.0144
1974	182,444	17,693	3219	4493	0.0246	0.0176
1973	183,000*	16,769	3224	?	--	--
1972	182,000	16,043	2604	9439	0.0519	0.0143
1971	177,000	16,356	2439	8917	0.0504	0.0138
1970	167,000	21,130	3745	7385	0.0442	0.0224
1969	154,000	21,399	3469	4930	0.0320	0.0225
1968	140,000	20,157	2601	3556	0.0254	0.0186
1967	122,000	19,996	2745	?	--	--

* At the close of 1973, there was a purging of the Airmen Certification files. During this process, approximately 26,000 duplicates or faulty records were eliminated. In order to account for this purging, 16,000 were subtracted from all earlier private pilot totals, 10,000 from commercial, and 26,000 from instrument ratings.

Airline Transport Pilot Departure Rate (ATPD)

Airline transport pilot departure rate ATPD is calculated according to

$$ATPD = ATPDN*ATP$$

where the airline transport pilot departure rate normal (ATPDN = 0.025) is an exponentially smoothed average of the annual values presented in Table 10 The reciprocal of ATPDN indicates an average ATP lifetime of 40 years.

Instrument-Rated Pilots (IP)

The assumption being made is that all new commercial certificates will also have an instrument rating. Therefore, the number of instrument-rated pilots IP at any point in time is calculated as the instrument-rated pilot population at the preceding point in time, plus the number of private pilots obtaining an instrument rating during the intervening interval, plus the number of commercial certificates issued, minus the instrument-rated pilot departures.

$$IP_t = IP_{t-1} + DT(URIP + CCI - IPD)$$

IP_t: Instrument-rated pilots at time t (people)
URIP: Upgrade rate to instrument from private (people/year)
IPD: Instrument-rated pilot departure rate (people /year).

Instrument-Rated Pilot Departure Rate (IPD)

Annual values for the instrument-rated pilot departure rate normal IPDN are given in Table 11. Recalling that the airmen files were purged at the close of 1973, it is impossible to determine a valid data

t

TABLE 10. AIRLINE TRANSPORT PILOT DEPARTURE RATE NORMAL

	Airline Transport Certificates As of Jan. 1	Airline Transport Certificates Issued During	Airline Transport Pilot Departures During	ATPDN
1977	45,072	--	--	--
1976	42,592	3869	1389	0.0326
1975	41,002	2765	1175	0.0287
1974	38,139	3219	356	0.0093
1973	37,714*	3224	2799	?
1972	35,949	2604	839	0.0233
1971	34,430	2439	920	0.0267
1970	31,442	3745	757	0.0241
1969	28,607	3469	634	0.0222
1968	25,817	2601	-189	?
1967	23,917	2745	845	0.0353
1966	22,440	1513	36	0.0016
1965	21,572	1177	309	0.0143

* At the close of 1973, there was a purging of the Airmen Certification files. During this process, approximately 26,000 duplicates or faulty records were eliminated. In order to account for this purging, 16,000 were subtracted from all earlier private pilot totals, 10,000 from commercial, and 26,000 from instrument ratings.

TABLE 11. INSTRUMENT-RATED PILOT DEPARTURE RATE NORMAL

	Instrument Ratings Held as of Jan. 1	Instrument Ratings Issued During	Instrument Rating Departures During	IPDN
1977	211,364	--	--	--
1976	203,954	18,155	10,745	.053
1975	199,323	16,495	11,864	.060
1974	185,969	19,012	5,385	.029
1973	162,000*	19,590	?	--
1972	153,000	17,311	8,311	.054
1971	144,000	17,207	8,207	.057
1970	130,000	20,204	6,204	.048
1969	113,000	20,628	3,628	.032
1968	97,000	17,972	1,972	.020
1967	81,000	19,255	3,255	.040
1966	68,000	14,192	1,192	.018

* At the close of 1973, there was a purging of the Airmen Certification files. During this process, approximately 26,000 duplicates or faulty records were eliminated. In order to account for this purging, 16,000 were subtracted from all earlier private pilot totals, 10,000 from commercial, and 26,000 from instrument ratings.

point for that year. FAA published figures for instrument-ratings held previous to January 1, 1974, were (somewhat) arbitrarily decreased by the 26,000 faulty records found during the file purge. In determining an annual value for IPDN, the difference in ratings held between successive years is more important than the actual number outstanding on a particular date. A smoothed value of IPDN through 1974 is 0.042 which implies an average instrument rating lifetime of 24 years. Instrument-rated pilot departure rate is

$$IPD = IPDN*IP$$

Upgrade Rate to Instrument From Private (URIP)

The rate at which private pilots are obtaining instrument-ratings is calculated by

$$URIP = URIPN*PP.$$

The annual values of URIPN in Table 12 yield a smoothed value of 0.015.

Helicopter Certificates Issued (HCI)

Figure 9 is a plot of the helicopter certificates issued during each year since 1964. As with student certificates, the mid-60s experienced a tremendous growth in the number of helicopter certificates issued annually. In the early 70s, the number of certificates issued has steadily decreased. In order to get some idea of the cost impact on certificates issued, the six most recent data points were assumed to be varying strictly because of the variable cost of operating piston helicopters. A log linear regression analysis yielded,

$$HCI = 2936 * VC(6)^{\underset{(4.87)}{-6.264}}$$

$$R^2 = 0.80$$
$$F_{1,6} = 23.8$$

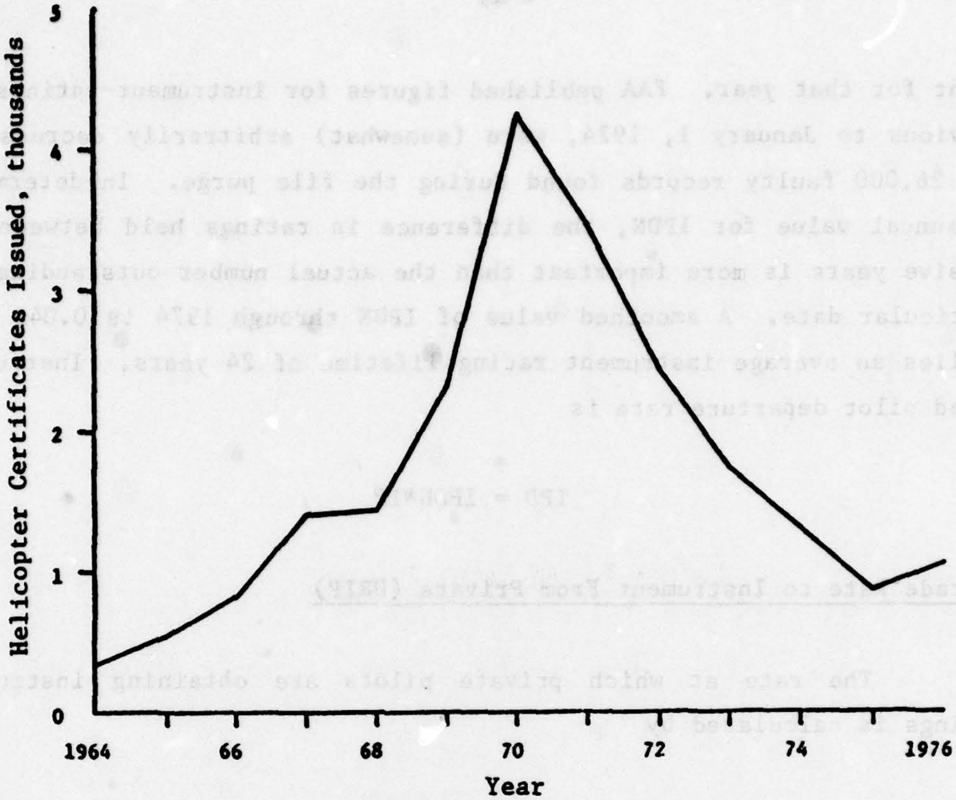

FIGURE 9. HELICOPTER CERTIFICATES ISSUED ANNUALLY

TABLE 12. NORMAL UPGRADE RATE TO INSTRUMENT-RATING FOR PRIVATE PILOTS

	Private Certificates As of Jan. 1	Instrument Rating Certificates Issued To Private During	URIPN
1977	309,005	--	--
1976	305,863	6,686	.0218
1975	305,848	4,670	.0153
1974	398,921	4,829	.0162
1973	307,000	4,587	.0149
1972	299,000	3,853	.0129
1971	290,000	3,625	.0118
1970	286,000	3,790	.0126
1969	268,000	3,556	.0125
1968	240,000	2,948	.0213

Helicopter Pilots (HP)

Helicopter pilots HP at any point in time are calculated as the helicopter pilot population at the preceding point in time, plus the number of helicopter certificates issued, minus the helicopter pilot departures.

$$HP = HP_{t-1} + DT(HCI - HPD)$$

HP_t: Helicopter pilots at time t (people)

HPD: Rate of helicopter pilot departures (people/year).

Helicopter Pilot Departure Rate (HPD)

Helicopter pilot departure rate HPD is calculated according to

$$HPD = HPDN*HP$$

Annual values for HPDN are given in Table 13; the exponentially smoothed average value for HPDN = 0.272. The reciprocal of HPDN indicates an average helicopter pilot lifetime of 3.7 years. This seems low, but many helicopter pilots eventually obtain a fixed wing certificate which represents a departure from the helicopter (only) category.

Helicopter-Rated Pilots (HR)

Helicopter-rated pilots are those pilots holding a fixed wing airman certificate with an additional rating for flying helicopters. Therefore, the number of helicopter-rated pilots HR at any point in time is calculated as the helicopter-rated pilot population at the preceeding

TABLE 13. HELICOPTER PILOT DEPARTURE RATE NORMAL

	Helicopter Certificates As of Jan. 1	Helicopter Certificates Issued During	Helicopter Pilot Departures During	HPDN
1977	4804	--	--	--
1976	4932	1064	1192	.242
1975	5647	866	1581	.280
1974	5968	1298	1619	.271
1973	(7987)*	1719	(3738)	(.468)
1972	7992	2421	2426	.304
1971	6677	3448	2133	.319
1970	4286	4250	1859	.434
1969	3166	2326	1206	.381
1968	2573	1433	840	.326
1967	1819	1411	657	.361
1966	1392	822	395	.284
1965	1058	549	215	.203
1964	823	344	109	.132

* At the close of 1973, there was a purging of the Airmen Certification files. During this process, approximately 26,000 duplicates or faulty records were eliminated. In order to account for this purging, 16,000 were subtracted from all earlier private pilot totals, 10,000 from commercial, and 26,000 from instrument ratings.

point in time, plus the number of new helicopter ratings issued, minus the helicopter-rated pilot departures.

$$HR_t = HR_{t-1} + DT(HRI-HRD)$$

HR_t: Helicopter-rated pilots at time t (people)
HRI: Helicopter-ratings issued rate (people/year)
HRD: Helicopter-ratings departure rate (people/year)

Helicopter-Rated Pilot Departure Rate (HRD)

Table 14 indicates that commercial certificated pilots hold approximately ten times as many helicopter ratings as either private pilots or others. The assumption was made that the fractional rate of departure for helicopter rated pilots HRDN will equal the fractional rate of departure for commercial pilots CPDN,

$$HRD = HRDN*HR$$

where HRDN = 0.046/year.

TABLE 14. HELICOPTER RATINGS

	Commercial Airplane, Commercial Helicopter	Private Airplane, Commercial Helicopter	Other Helicopter Ratings
1977	18,780	2109	2123
1976	18,996	1965	1979
1975	19,247	1948	1777
1974*	(18,335)	(1944)	(1515)
1973	19,507	2079	1568
1972	18,326	1839	428
1971	16,422	1441	1382
1970	14,374	997	1239

* At the close of 1973, there was a purging of the Airmen Certification files. During this process, approximately 26,000 duplicates or faulty records were eliminated. In order to account for this purging, 16,000 were subtracted from all earlier private pilot totals, 10,000 from commercial, and 26,000 from instrument ratings.

Helicopter-Ratings Issued (HRI)

Since commercial certificated pilots are the predominant holders of additional helicopter ratings, the rate of issuance of additional helicopter ratings is assumed to be directly proportional to the number of active commercial pilots. Table 15 presents the data used in deriving the fractional helicopter-ratings-issued-normal HRIN. Note that the helicopter rating departures recorded in Table 15 are values derived from the above expression for HRD.

$$HRI = HRIN*CP$$

The value of HRIN appears to be steadily decreasing during the time interval of valid data. The exponentially smoothed value is, HRIN = 0.013.

TABLE 15. HELICOPTER RATINGS ISSUED NORMAL

	Additional Helicopter Ratings As of Jan. 1	(Derived) Helicopter Rating Departures During	Helicopter Ratings Issued During	Commercial Certificates As of Jan. 1	HRIN
1977	23,012	--	--	187,801	--
1976	22,940	1,835	1,907	189,342	.010
1975	22,971	1,884	1,853	192,425	.010
1974	21,794	1,046	2,223	182,444	.012
1973	23,154	--	--	183,000	--
1972	21,593	1,036	2,597	182,000	.014
1971	19,245	924	3,272	177,000	.018
1970	16,610	797	3,432	167,000	.021

Summarization of the Pilot Sector

At this point, it may be useful to summarize the development of the structure within the pilot supply sector. Actual data for the numbers of active pilots and the number of pilot certificates issued were obtained from readily available FAA records. Whereas, classical econometric approaches relate pilot population directly to other socioeconomic variables, the most realistic approach requires further development of the system's structure.

The progression of pilots upgrading from one competency level to another was characterized as a birth-death process. Estimates for each upgrade (birth) rate and each departure (death) rate were developed from the FAA data. In all cases, the departure rate was estimated to be a constant fraction of the corresponding active pilot population. The rate of student certificates being issued was found to depend on both the relative cost of operating single engine aircraft and the relative level of individual affluence. Both the rate of commercial and airline transport certificates being issued were found to be dependent upon the level of commercial air carrier activity; commercial certificates issued also depends on the relative cost of flying.

In conclusion, the active pilot population is driven by the rate of student certificates issued. The number of new student pilots is directly proportional to the U.S. population and is extremely dependent on the cost of flying and the level of individual affluence.

CHAPTER 4. THE DYNAMICS OF AIRCRAFT DEMAND

The dynamic behavior within the general aviation system is the result of continuous causal interactions between the pilot supply sector, the aircraft utilization sector, and the aircraft demand sector. Because the interdependence between the aircraft utilization and demand sectors is so strong, they are presented simultaneously for each user category. In the following sections, detailed historical data that were used in statistically estimating each of the critical relationships are discussed.

PRIMARY USE - BUSINESS

Business use is defined by the FAA to include any use of an aircraft not for compensation or hire by an individual for the purposes of transportation required by a business in which he is engaged. An important distinction here is that the business aircraft is owned and operated by the same individual. Typically, such persons use their aircraft primarily for business and partly for pleasure.

Since the business aircraft owner must hold an active pilot certificate, the goal for desired active business aircraft should be related to the number of active pilots. In particular, consider a new parameter DPAA(I,J), desired-pilots-per-aircraft, which can translate the active pilot population into a desired number of business aircraft,

$$DAA(I,J) = \frac{PP + CP + ATP}{DPPA(I,J)}$$

DPPA is not likely to be a constant but should be reflective of general economic conditions and the relative cost of ownership. Furthermore, the propensity for active pilots to demand business aircraft will vary among the particular aircraft types. Thus, distinct relationships are developed for each DPPA corresponding to each significant aircraft type within the business use category.

The annual hours flown within the business use category should reflect some average aircraft utilization rate for each particular aircraft type. Furthermore, these average utilization rates may be expected to depend on both general economic conditions and the variable cost of operating general aviation aircraft. Relationships for each average aircraft utilization rate are developed within the following sections.

Single-Engine Piston

In order to derive statistical relationships for the critical relationships describing behavior within the business/single-engine piston subsegment, an historical data base must first be developed. FAA general aviation activity data are based upon information submitted by aircraft owners on AC Form 8050-73, "Aircraft Registration Eligibility, Identification and Activity Report". As of January 1, 1971, the definition used for determining the active general aviation fleet was changed. Formerly, an active aircraft was one certificated as eligible to fly. Now an active aircraft must have a current registration and have been flown during the previous calendar year. Active aircraft are categorized according to the primary use of that aircraft during the previous year; that is, the primary use of the aircraft is determined by whatever use has the most hours flown recorded. Annual hours flown by each aircraft are reported according to their actual use. Thus, an aircraft used primarily for business may also show a significant number of personal use hours.

An estimate of the net number of aircraft activations during any year can be derived from the number of active aircraft outstanding in successive years and the number of aircraft destroyed. The aircraft activation rate represents the combined effect of new or used aircraft purchases, aircraft deactivations, and aircraft transfers to different primary use categories. Using derived values for the number of single-engine business aircraft destroyed during each year, the aircraft activation rate can be estimated as shown in Table 16.

TABLE 16. ESTIMATED DESIRED-PILOTS-PER AIRCRAFT IN THE BUSINESS/SINGLE ENGINE PISTON SUBSEGMENT

Year	AA(1,1) as of Jan. 1	Derived ADR(1,1) during	Derived AAR(1,1) during	TP= PP+CP+ATP Jan. 1	Estimated DPPA(1,1) during
1971	20,522	94	-344	501,000	25.26
1972	20,084	93	1549	517,000	22.30
1973	21,540	114	3943	528,000	17.94
1974	25,369	125	768	519,504	19.31
1975	26,012	131	899	539,275	19.39
1976	26,780	140	1844	537,797	17.65
1977	28,484	-	-	541,878	-

Figure 10 shows a plot of AAR(1,1) during the six years for which data are available. At first glance this activation rate looks like it would be especially difficult to explain. However, recalling the functional definition for aircraft activation rate

$$AAR(I,J) = \frac{DAA(I,J) - AA(I,J)}{AT(I,J)}$$

and substituting the expression for DAA(1,1), yields for the business/single-engine piston subsegment

$$AAR(1,1) = \frac{\dfrac{PP + CP + ATP}{DPPA(1,1)} - AA(1,1)}{AT(1,1)}$$

Solving for DPPA(1,1),

$$DPPA(1,1) = \frac{PP + CP + ATP}{AT(1,1) * AAR(1,1) + AA(1,1)}$$

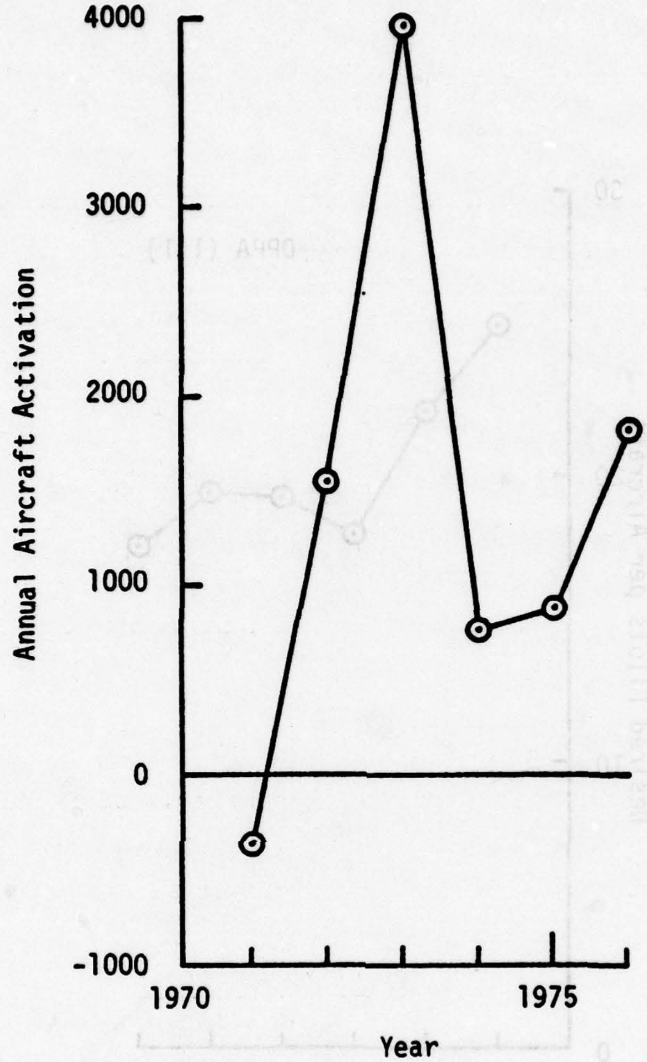

FIGURE 10. BUSINESS SINGLE ENGINE AIRCRAFT ACTIVATIONS

Because of the discrete nature of data reporting on an annual basis, AT(1,1), the average delay time in adjusting for a discrepancy between the desired number of aircraft and the actual active aircraft, was assumed to be an integer value; the ultimate choice being dictated by the best fit of the data. At an adjustment time of two years, the desired-pilot-per-aircraft values calculated from the above equation are given in Table 16. Figure 11 shows the variation of DPPA(1,1) over time, which doesn't appear to be any better than the activation rate.

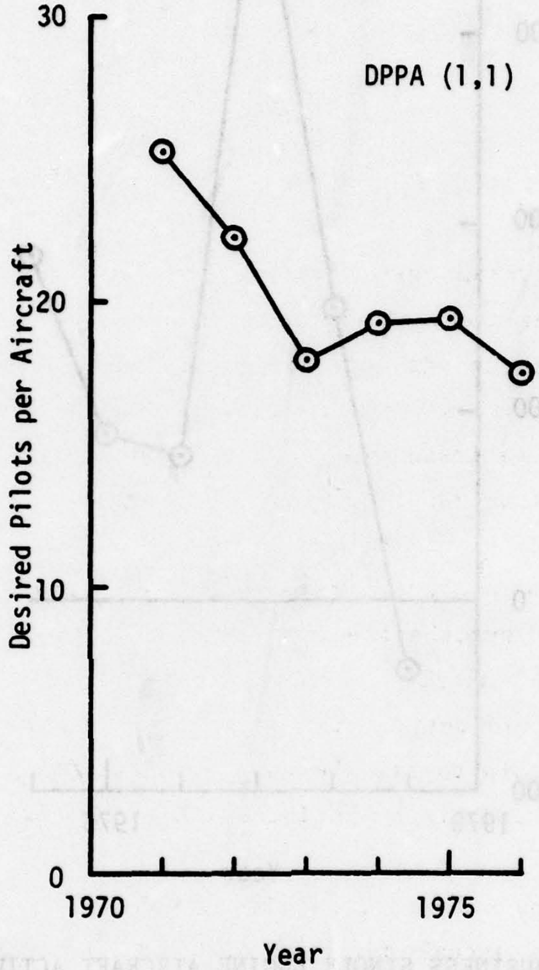

FIGURE 11. DESIRED PILOTS PER AIRCRAFT RATIO IN THE BUSINESS/SINGLE-ENGINE SUBSEQUENT

DPPA is not expected to be a constant but should be reflective of general economic conditions and/or the relative cost of aircraft ownership. Using the time series values for DPPA(1,1), GNP values indexed to 1972 and measured in constant 1972 dollars, and similar indices for the fixed cost of ownership and the total (fixed + variable)

cost of aircraft ownership, the following equation was developed through a multiple linear regression analysis.

$$\text{DPPA}(1,1) = 21.5 * \text{GNP}^{-2.80}$$
$$(-8.21)$$

$$R^2 = 0.94$$

$$F_{1,4} = 67.3$$

Both fixed cost and total cost of ownership were statistically insignificant in explaining the variation in DPPA(1,1).

The GNP data used in estimating this equation only encompasses a range from 0.94 to 1.09 (indexed to and measured in 1972 dollars). Realizing that the ultimate use of the model will undoubtedly be required to extrapolate GNP far past the limits experienced, it is extremely important to construct a functional form that will not lead to ridiculous conclusions in the future. In particular, had a strictly linear function been hypothesized for the dependence of DPPA(1,1) on GNP, DPPA(1,1) would rapidly decrease as GNP increased. Eventually, every active pilot would desire his own business aircraft. By using an exponential relationship to fit the data, the resulting expression does not show as great a sensitivity to increases in GNP past the historical scope of data.

Annual business hours flown by actual use is best measured in terms of the average annual aircraft utilization rates. Intuitively, the individual aircraft utilization rates might be expected to be dependent on both the level of economic activity and the variable cost of operating the aircraft. Figure 12 illustrates how relatively constant the average aircraft utilization rate has been for single-engine aircraft. No correlation could be determined between this average utilization rate and any plausible independent variables. The average value is

$$\text{AUR}(1,1) = 156 \ \frac{\text{hr/aircraft}}{\text{year}}$$

The annual hours flown within this subsegment of general aviation is then, simply

$$HF(1,1) = AUR(1,1) * AA(1,1)$$

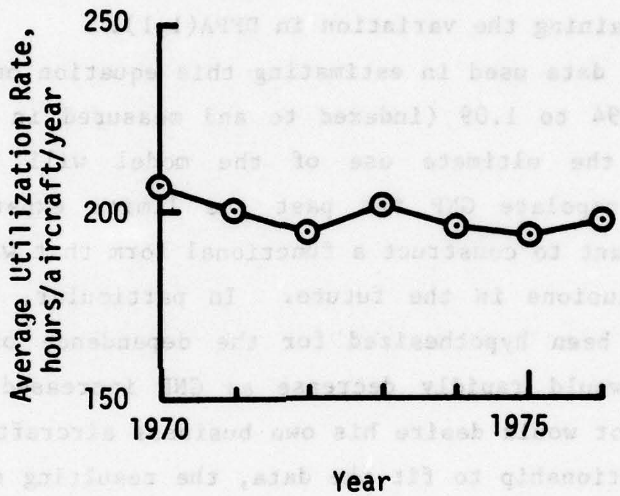

FIGURE 12. AVERAGE ANNUAL AIRCRAFT UTILIZATION RATES FOR BUSINESS/SINGLE-ENGINE AIRCRAFT

Multi-Engine Piston

Following the same reasoning used in deriving the equations for the business/single-engine subsegment, Table 17 shows the annual number of aircraft activations within the business/multi-engine subsegment and the estimated values for DPPA(1,3) for an adjustment time AT(1,3) of 3 years.

TABLE 17. ESTIMATED DESIRED-PILOTS-PER-AIRCRAFT IN THE BUSINESS/MULTI-ENGINE PISTON SUBSEGMENT

Year	AA(1,3) as of Jan. 1	Derived ADR(1,3) during	Derived AAR(1,3) during	TP=PP+CP +ATP as of Jan. 1	Estimated DPPA(1,3) during
1971	6103	37	58	501,000	79.82
1972	6124	39	547	517,000	66.58
1973	6632	44	747	528,000	59.51
1974	7335	49	447	519,504	59.88
1975	7733	46	239	539,275	63.82
1976	7926	50	565	537,797	55.90
1977	8441	-	-	541,878	-

The trend of aircraft activations over time is illustrated in Figure 13. The most significant results of a log-linear multiple regression analysis are

$$DPPA(1,3) = 66.1 * \underset{(-9.01)}{GNP^{-2.90}} * \underset{(1.45)}{FC(1,3)^{0.23}}$$

$$R^2 = 0.98$$

$$F_{2,3} = 67.6$$

where FC(1,3) represents the fixed cost of owning business/multi-engine aircraft.

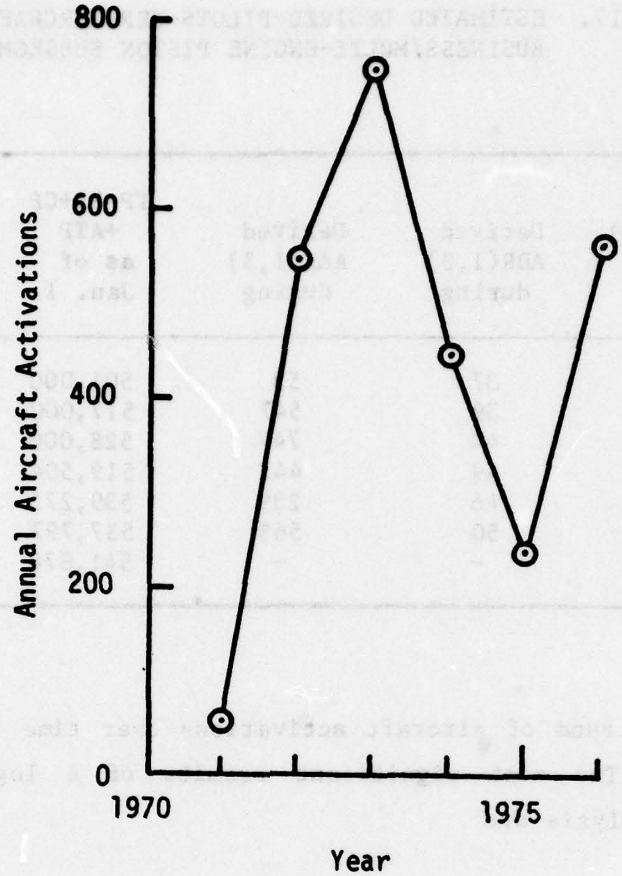

FIGURE 13. BUSINESS/MULTI-ENGINE PISTON AIRCRAFT ACTIVATIONS

Figure 14 shows the average annual utilization rates for this type of aircraft.

Results of multiple regression analyses applied to these data indicate

$$AUR(1,3) = 202 * \underset{(-1.84)}{VC(3)^{-0.268}}$$

$$R^2 = 0.40$$

$$F_{1,5} = 3.37$$

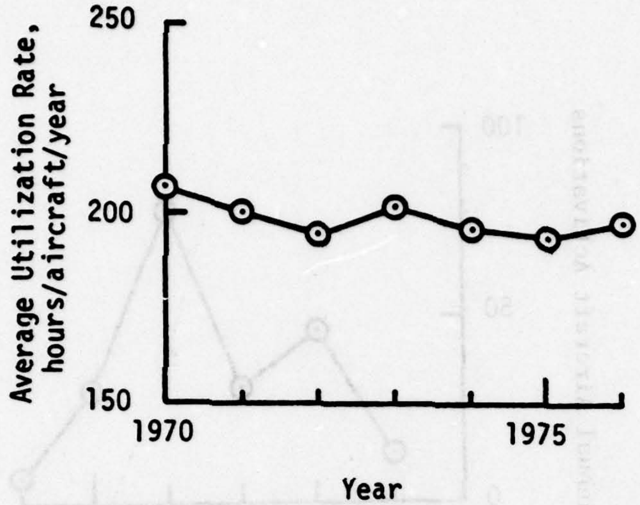

FIGURE 14. AVERAGE ANNUAL AIRCRAFT UTILIZATION RATES FOR BUSINESS/MULTI-ENGINE PISTON AIRCRAFT

<u>**Piston-Engine Helicopter**</u>

Table 18 shows the annual number of aircraft activations within the business/piston helicopter subsegment and the estimated values for DPPA(1,6) corresponding to an AT(1,6) of one year.

TABLE 18. ESTIMATED DESIRED-PILOTS-PER AIRCRAFT IN THE BUSINESS/PISTON-ENGINE HELICOPTER SUBSEGMENT

Year	AA(1,6)	ADR(1,6)	AAR(1,6)	HP	DPPA(1,6)
1971	233	2	13	25,922	105.7
1972	244	2	46	29,585	102.0
1973	288	2	31	31,141	97.6
1974	317	2	78	27,762	70.3
1975	393	3	30	28,618	67.7
1976	420	3	7	27,872	65.3
1977	424	-	-	27,816	-

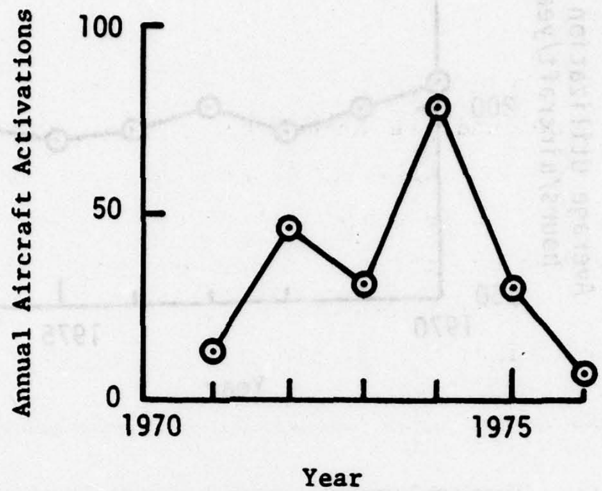

FIGURE 15. BUSINESS/PISTON HELICOPTER ACTIVATIONS

The annual number of aircraft activations is illustrated graphically in Figure 15. Results of multiple regression analyses indicate the following relationship

$$DPPA(1,6) = 93.1 * \underset{(5.52)}{TCP(1,6)^{1.91}} * \underset{(3.93)}{GNP^{-2.65}}$$

$$R^2 = 0.97$$

$$F_{2,3} = 56.1$$

and for the average utilization rate,

$$AUR(1,6) = 243 * \underset{(-6.15)}{GNP^{-2.048}}$$

$$R^2 = 0.88$$

$$F_{1,5} = 37.8$$

Business Use Summary

At this point, it may be useful to summarize the development of the structure within the business user category. Both the active aircraft fleet size and the annual hours flown by aircraft type were assembled from readily available FAA data records. Whereas a classical econometric approach would probably relate fleet size directly to other socioeconomic variables, the system dynamics approach requires further development of the system's structure.

In particular, the net aircraft activation rate was related to the system's goal for a desired number of active aircraft. This goal, desired active aircraft, was further refined by relating it to the active pilot population through the concept of a desired-pilots-per-aircraft ratio. Each of the desired-pilots-per-aircraft relationships was shown to be dependent upon the level of GNP. Figure 16 illustrates the fundamental mechanisms controlling activity within the business use/multi-engine piston subsegment. The more expensive aircraft types also showed a correlation with the total cost of owning and operating the aircraft. Particularly encouraging is the fact that the elasticities of GNP corresponding to the three different aircraft types are virtually identical -- estimated values range from -2.65 to -2.93.

Because business aircraft are owned and operated by the same individual, the most logical approach to projecting future levels of annual hours flown is to base these projections on the average annual utilization rates of each distinct aircraft type. Time series values for the average utilization rates by each aircraft type were developed and investigated for any possible correlation with other socioeconomic variables. A priori considerations would suggest that as the variable cost of aircraft operation increased, the annual use of the aircraft would decrease. Alternately, one might expect that as economic activity increased, other things being equal, the level of utilization would also increase. However, the historical data confirms the variable cost hypothesis only for multi-engine aircraft. Economic activity is significant only for piston helicopters, and that possesses the opposite sign of

what was expected. The average utilization rates for single-engine aircraft have been essentially constant over time, independent of other exogenous influences.

In conclusion, the business aircraft fleet size is driven by the active pilot population. It is very sensitive to the national level of economic activity and only slightly affected by the cost of general aviation. Utilization of business aircraft is relatively constant with little dependence on other exogenous conditions.

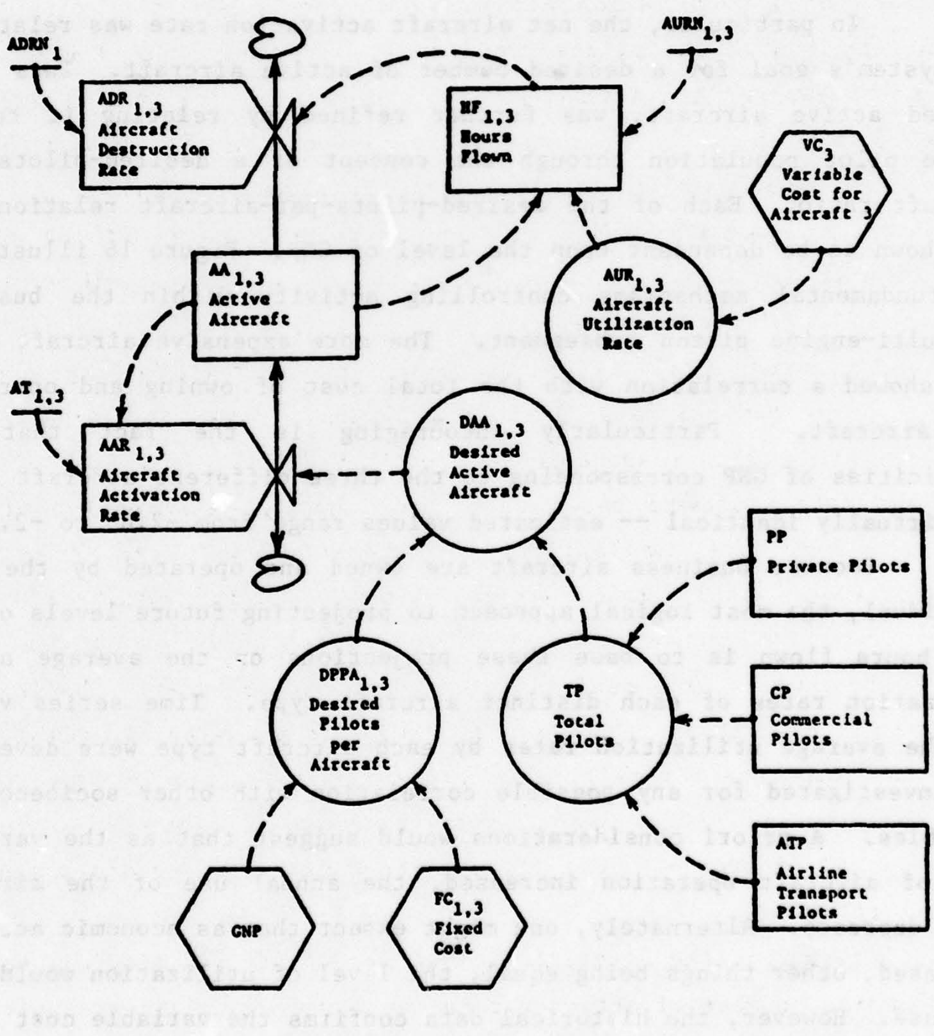

FIGURE 16. STRUCTURE OF THE BUSINESS/MULTI-ENGINE PISTON SUBSEGMENT

PRIMARY USE - CORPORATE

Corporate use is defined by the FAA to include any use of an aircraft by a corporation, company or other organization for the purpose of transporting its employees and/or property not for compensation or hire, and emloying professional pilots for the operation of the aircraft. There is no need to dwell on the motives for corporate aircraft ownership. Much of the benefit derives from the potential savings of executive's time, although the prestige factor can hardly be ignored.

Should a corporation obtain an aircraft, it is a relatively easy matter to hire the pilots required to fly it. Thus, there is no direct dependence on the active pilot population as was demonstrated in the business category. The number of corporate aircraft is neither restricted nor enhanced by the number of available pilots. It may be true that high level executives with a flying background encourage the use of corporate aircraft within their own companies, but the impact would be extremely difficult to measure.

The annual utilization of corporate aircraft is expected to vary about some nominal rate, in much the same way as for business aircraft. However, it is reasonable to expect that the utilization of corporate aircraft would be based on a more thorough examination of the costs involved. The availability of commercial air carrier service might also have a strong influence on corporate aircraft utilization.

The basic mechanism determining the demand for corporate aircraft is the demand for a desired number of active aircraft. Unlike the business category, there is no transformation from the active pilot population to corporate aircraft demand. It is reasonable to expect that the desired number of corporate aircraft would be dependent upon the national level of economic activity and the cost of owning and operating these aircraft.

Rearranging the aircraft activation equation, historical values for the desired number of active aircraft are determined according to,

$$DAA = AT * AAR + AA$$

where the subscripts of each variable are consistent with the significant aircraft types within the corporate category. Active aircraft data, AA, are available directly from FAA historical records. Values for the annual aircraft activation rates, AAR, are derived in a manner similar to that for the business category. The adjustment time, AT, for each aircraft type is chosen to be an integer value which best explains the variation in annual data.

A variety of regression analyses were made using these data. Those results finally used in the model are shown in Table 19. These show the goal, desired active aircraft, to be a function of gross national product and, for one aircraft type, a function of the total cost of owning and operating the aircraft. Strictly linear functional forms were used to prevent DAA from rising too rapidly as GNP increases from the present value.

TABLE 19. CORPORATE AIRCRAFT DEMAND EQUATIONS
(t - values in parenthesis)

	$\underline{R^2}$	$\underline{F}$
DAA(2,1) = -3199 + 4357 * GNP (3.33)	0.73	$F_{1,4}$ = 11.1
DAA(2,3) = -5242 + 10,146 * GNP -732 * TCP(2,3) (6.40) (0.56)	0.94	$F_{2,3}$ = 22.1
DAA(2,4) = -4431 + 5846 * GNP (2.52)	0.61	$F_{1,4}$ = 6.4
DAA(2,5) = -5504 + 6849 * GNP (3.94)	0.80	$F_{1,4}$ = 3.8
DAA(2,7) = -1733 + 2036 * GNP (1.96)	0.70	$F_{1,4}$ = 3.8

Note that if economic growth were curtailed such that the GNP (measured in constant 1972 dollars) remained constant, the goal for most active corporate aircraft would also remain constant. Eventually the aircraft activation rate would equal replacement of destroyed aircraft only.

As can be seen, the proportion of the variance explained is not impressive but the level of statistical significance in relation to the GNP is high. These statistical results support the argument that the level of national economic activity plays an important, perhaps the most important, role in determining the demand for corporate aircraft. How much of the unexplained variance may be attributable to noise in the data, nonlinearity, or other causal mechanisms has yet to be determined. Furthermore, the prestige associated with operating corporate aircraft is felt to be important, but this relationship was never quantified.

In determining the total annual corporate fleet hours flown, the decision being modeled is the decision of the corporate aircraft owners to fly their own aircraft. Given that a corporation has purchased its own aircraft, theoretically it must still evaluate the cost of transporting its employees on each potential trip relative to the cost of alternate means of travel. Total cost benefits derived from utilizing their own aircraft can include both direct out-of-pocket cost savings and employee time savings. Attempts have been made to quantify the value of an executive's time, but the results are not particularly useful here.

Thus, the primary expectation was that average corporate aircraft utilization rates would be related to the variable cost of operating these aircraft. The regression analyses also looked into the possibility that levels of economic activity and air carrier activity might explain some of the variance in annual utilization rates. Table 20 presents the most significant results.

TABLE 20. CORPORATE AIRCRAFT UTILIZATION EQUATIONS
(t - values in parenthesis)

Equation	t-values	R^2	F
$AUR(2,1) = 224$ hr/aircraft/yr			
$AUR(2,3) = 362 * VC(3)^{-0.466}$	(-6.44)	0.89	$F_{1,5} = 41.6$
$AUR(2,4) = 499 * VC(4)^{-2.192} * RAD^{-1.500}$	-6.52; (-3.32)	0.94	$F_{2,4} = 28.8$
$AUR(2,5) = 504 * VC(5)^{-0.287}$	(-1.32)	0.26	$F_{1,5} = 1.75$
$AUR(2,7) = 419 * VC(7)^{-0.436} * GNP^{-0.409}$	(-1.13); (-0.96)	0.52	$F_{2,4} = 2.14$

With the exception of relatively inexpensive single-engine aircraft, the variable cost is the most significant parameter in explaining variations in annual aircraft utilization rates. The sign on each exponent of the variable cost agrees with a priori expectations, but only the behavior of turboprop aircraft operators appears to be elastic (i.e., an elasticity, 2.192, greater than one) with respect to variable cost. Each of the other aircraft types indicate rather low elasticities of between 1/4 and 1/2 percent. The level of commercial airline activity, indicated by a normalized measure of revenue aircraft departures (RAD), is quite significant in explaining variations in turboprop utilization rates.

GNP appears only in the turbine powered helicopter relationship, and there with only a slight significance. At first glance, the sign on the exponent of GNP may appear to be opposite the a priori expectation; that is, the results indicate an increase in GNP causes a decrease in the average utilization rates. A potential explanation to this apparent paradox is that, according to the corporate turbine powered helicopter demand equation presented in Table 19, as GNP decreases, the desired number of active helicopters decreases, driving out the marginal users and resulting in a higher overall utilization rate but a lower number of total hours flown.

Figure 17 shows the fundamental mechanisms that generate activity within the corporate use/turbojet subsegment.

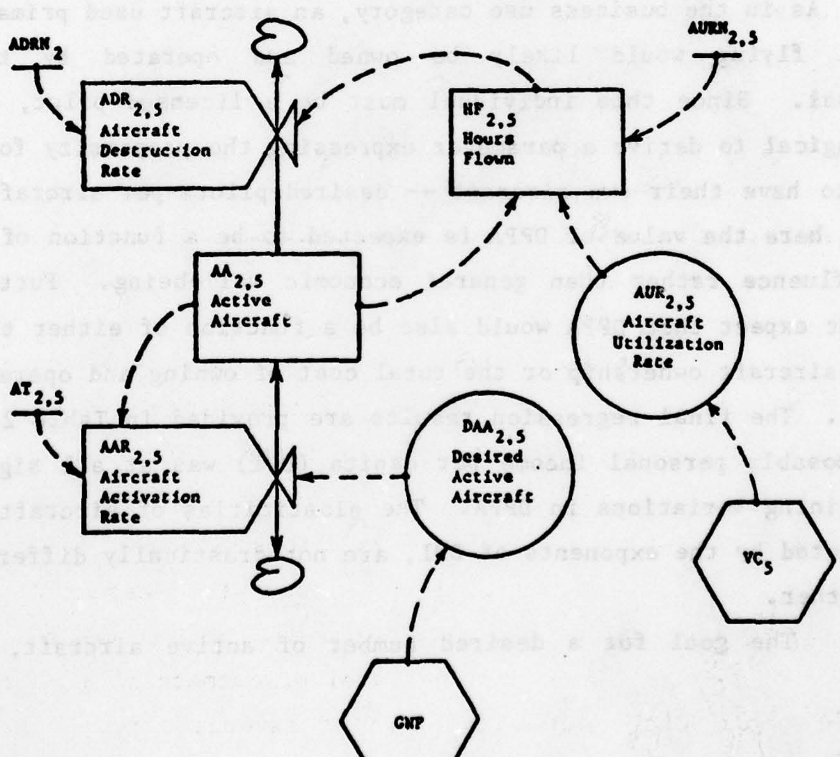

FIGURE 17. STRUCTURE OF THE CORPORATE/TURBOJET SUBSEGMENT

PRIMARY USE - PERSONAL

The FAA defines personal use to be any use of an aircraft for personal purposes not associated with a business or profession, and not for hire. This includes maintenance of pilot proficiency.

Nearly 50 percent of the active general aviation fleet are used primarily for personal flying. However, they only fly an estimated 25 percent of the annual hours flown.

Nevertheless, it is the jet-set, playboy image of the personal flyer which many of the general aviation professional organizations are trying to dispel. Public attention has been recently focused on the personal flier, because of a number of spectacular mid-air crashes. This has led to a demand that general aviation be subjected to stricter regulation and even that the growth of general aviation be curtailed.

As in the business use category, an aircraft used primarily for personal flying would likely be owned and operated by the same individual. Since this individual must be a licensed pilot, it again seems logical to derive a parameter expressing the propensity for active pilots to have their own aircraft -- desired-pilots-per-aircraft, DPPA. However, here the value of DPPA is expected to be a function of individual affluence rather than general economic well-being. Furthermore, one might expect that DPPA would also be a function of either the fixed cost of aircraft ownership or the total cost of owning and operating the aircraft. The final regression results are provided in Table 21. Only the disposable personal income per capita (DPI) was at all significant in explaining variations in DPPA. The elasticities of aircraft demand, as indicated by the exponents of DPI, are not drastically different, one from another.

The goal for a desired number of active aircraft, DAA, is simply,

$$DAA(3,J) = \frac{PP + CP + ATP}{DPPA(3,J)}; \qquad J = 1,3,6$$

TABLE 21. PERSONAL AIRCRAFT DEMAND EQUATIONS
(t - values in parenthesis)

	$\underline{R}^2$	$\underline{F}_{1,4}$
$DPPA(3,1) = 7.34 * DPI^{-1.03}$ (-2.01)	0.50	4.05
$DPPA(3,3) = 199 * DPI^{-1.47}$ (-1.43)	0.34	2.04
$DPPA(3,6) = 89.5 * DPI^{-0.701}$ (-1.82)	0.46	3.52

The decision made by a personal flyer on whether to fly or not is similar to the corporation which must decide on whether to use its corporate aircraft for a particular trip. Multiple regression analyses were applied to the average annual utilization rates, but none of the potential independent variables were significant in explaining annual variations in these rates. Table 22 shows the average values that are included in the model.

TABLE 22. PERSONAL AIRCRAFT UTILIZATION RATES
(exponentially smoothed valves)

AUR(3,1) = 104 hr/aircraft/yr

AUR(3,3) = 139 hr/aircraft/yr

AUR(3,6) = 25 hr/aircraft/yr

The basis for generating activity within the personal use/single-engine subsegment is illustrated on Figure 18.

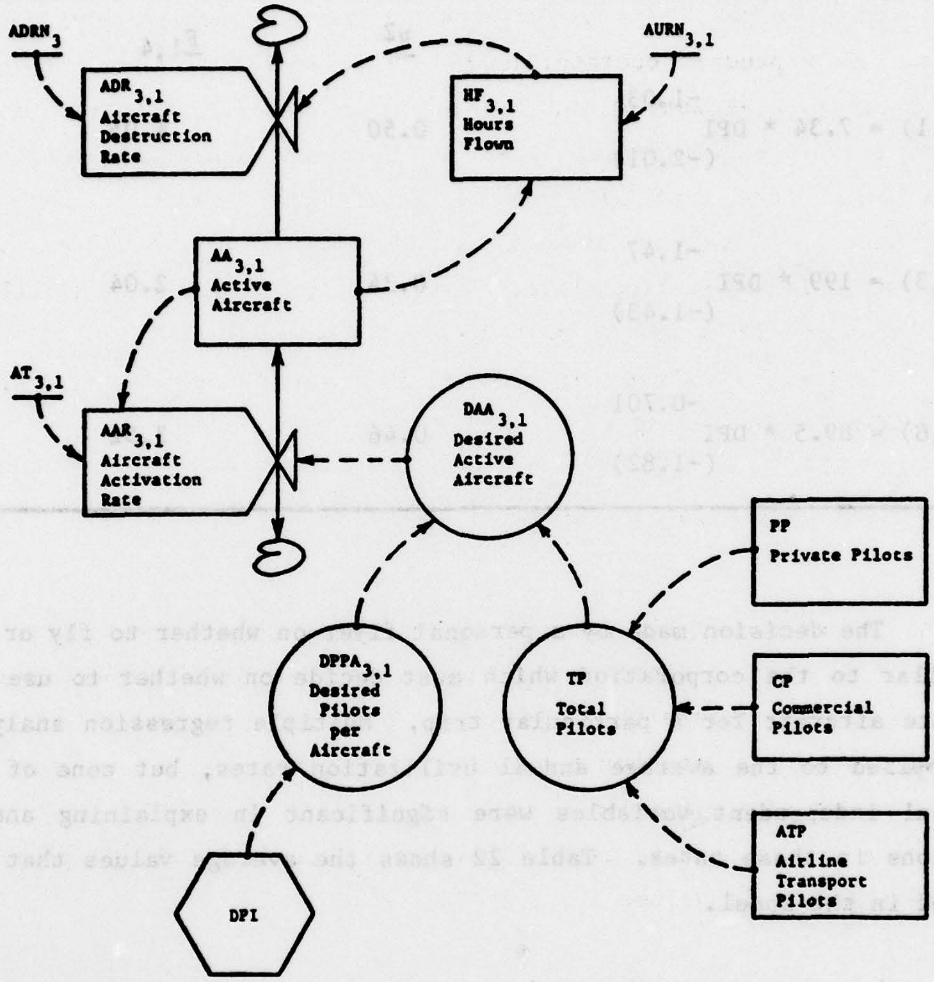

FIGURE 18. STRUCTURE OF THE PERSONAL/SINGLE-ENGINE PISTON SUBSEGMENT

PRIMARY USE - AERIAL APPLICATION

Aerial application in agriculture consists of those activities that involve the discharge of materials from aircraft in flight and a miscellaneous collection of minor related activities that do not require the distribution of any materials.

The annual hours flown within this category represent the satisfaction of a demand for service. It is this annual demand that determines subsequent behavior by the operators of these aircraft. For example, consider the crop-duster with a fleet of aerial application aircraft. As a prudent operator he will have some certain value for a desired aircraft utilization rate. Should the average utilization rates of his fleet surpass that value, then he will want to acquire additional aircraft to capture what may be some unsatisfied demand and, by so doing, reduce his fleet utilization rates to a more normal value. Conversely, should utilization rates decrease far below his threshold value, then he would be likely to reduce his fleet size.

Historical values for this desired-aircraft-utilization·rate can be determined according to

$$DAUR(4,J) = \frac{HF(4,J)}{DAA(4,J)}; \qquad J = 2,3,6$$

where DAA is derived in the usual way. One might expect that the threshold value for desired-aircraft-utilization-rate would be dependent upon the fixed cost of aircraft ownerhship; the larger the cost to be distributed, the more flying hours required to accomplish it. However, no significant correlation could be determined between the distinct DAUR values and their respective aircraft ownership costs. Table 23 presents the average threshold values inserted into the model.

TABLE 23. AERIAL APPLICATION AIRCRAFT DEMAND EQUATIONS

(Exponentially Smoothed Values)
DAUR(4,2) = 260 hr/aircraft/yr
DAUR(4,3) = 160 hr/aircraft/yr
DAUR(4,6) = 269 hr/aircraft/yr

Given the present mix of large and small farms within the U.S., there should be a saturation level for total annual aerial application hours flown at which every potential candidate for aerial application services is making full use of them. This reasoning suggests that the growth in annual aerial application hours will follow the so-called logistics or S-growth curve. A least squares fit of the form

$$Y = \frac{S}{e^{a*b^T}}$$

to the data of Figure 19 yields,

$$\sum_{J = 2,3,6} HF(4,J) = \frac{4.6 \times 10^6}{e^{1.233(.921)^t}}$$

where t = 0 at 1970. This relationship indicates an ultimate saturation level for aerial application equal to 4.6 million hours per year, or approximately twice the 1976 level.

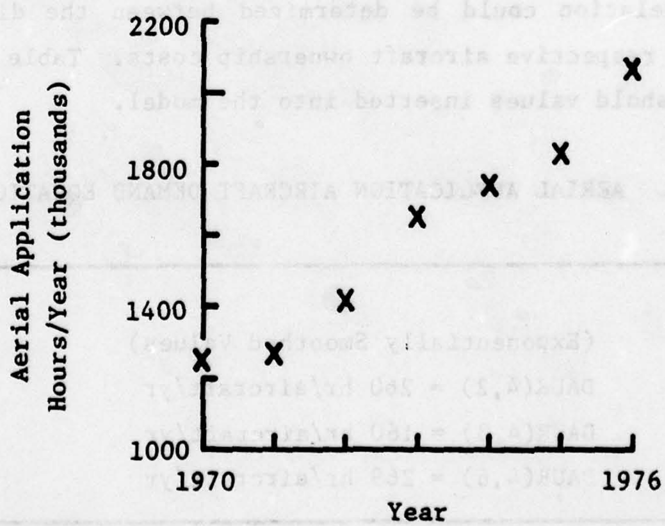

FIGURE 19. ANNUAL HOURS FLOWN IN AERIAL APPLICATION

In order to determine the demand for each of the three aircraft types used in aerial application, these total annual hours must be distributed between aircraft types 2, 3, and 6. Table 24 shows the fraction of total hours that have been flown by each aircraft type over the historical period. Since there is no apparent increasing preference for either aircraft types, an exponentially smoothed value was chosen for the fraction to be applied to future forecasts.

TABLE 24. FRACTION OF TOTAL AERIAL APPLICATION HOURS FLOWN BY EACH AIRCRAFT TYPE

Year	Single-Engine Piston, Aerial Application	Multi-Engine Piston	Piston Helicopter
1970	.987	.022	.081
1971	.907	.021	.071
1972	.888	.025	.087
1973	.900	.029	.071
1974	.900	.025	.073
1975	.906	.024	.070
1976	.899	.029	.072
Exponentially Smoothed Average	.900	.026	.074

For example, the annual hours flown by multi-engine piston aircraft will become,

$$HF(4,3) = 0.026 * \sum_{J = 2,3,6} HF(4,J)$$

and, since annual hours flown are determined directly, the desired-active-aircraft can be derived from,

$$DAA(4,J) = \frac{HF(4,J)}{DAUR(4,J)}; \quad J = 2,3,6$$

The aircraft activation rate, as always, is then

$$AAR(4,J) = \frac{DAA(4,J) - AA(4,J)}{AT(4,J)}; \quad J = 2,3,6$$

Figure 20 shows the proposed structure of the aerial application/single-engine subsequent.

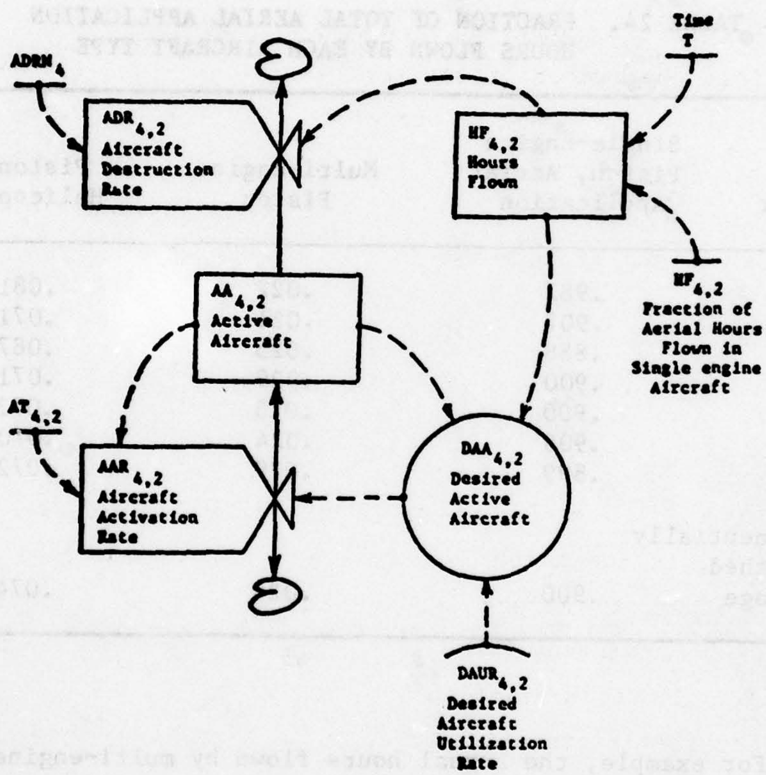

FIGURE 20. STRUCTURE OF THE AERIAL/SINGLE-ENGINE PISTON SUBSEGMENT

PRIMARY USE - INSTRUCTIONAL

Instructional flying is defined by the FAA to be any use of an aircraft for the purposes of formal instruction with the flight instructor aboard or with the maneuvers on the particular flight(s)

specified by the flight instructor. It is dominated by instruction leading to the private pilot's license; but it should directly reflect the number of all new certificates and ratings being issued.

As in the aerial application category, the key to describing behavior within the instructional category is to first correctly identify the total annual instructional hours demanded. These total hours represent demand for a service, a demand which will be satisfied by a fleet of adequately utilized instructional aircraft.

Total instructional hours flown in fixed wing aircraft were regressed against the number of student certificates issued, private certificates issued, and either commercial certificates issued or instrument ratings issued. The latter two types were segregated because they are themselves highly correlated; furthermore, in order to qualify for future commercial certificates, the pilot must also hold an instrument rating. The most significant results are,

$$\sum_{J=1,3} HF(5,J) = \underset{(0.45)}{34.1 * PCI} + \underset{(0.65)}{63.6 * IRI} + \underset{(0.60)}{14.9 * SCI}$$

where the equation was forced to pass through the origin and to be strictly linear in the number of private certificates issued (PCI), the number of instrument ratings issued (IRI), and the number of student certificates issued (SCI).

Although the statistical significance of the coefficients is not high, their interpretation is most logical. The estimated values suggest that the average student pilot receives almost 15 hours of instructional flying which is entirely reasonable, considering the student pilot departure (drop-out) rate derived in Chapter 3. Those student pilots, who ultimately complete their training and obtain a private certificate, receive an additional 34 hours prior to private status. The regression results further indicate that an individual spends, on the average, another 64 hours of instructional time beyond the private certificate in obtaining an instrument rating.

These aggregate instructional hours must be distributed among single-engine and multi-engine piston aircraft. Table 25 indicates the

historical fractions of fixed wing instructional hours flown within each type of aircraft. Again there is no apparent trend in the preference for either aircraft type, so an exponentially smoothed average is used to distribute the total hours.

TABLE 25. FRACTION OF FIXED WING INSTRUCTIONAL HOURS FLOWN

Year	Single-Engine Piston	Multi-Engine Piston
1970	.977	.023
1971	.969	.031
1972	.968	.032
1973	.966	.034
1974	.960	.040
1975	.963	.037
1976	.967	.033
Exponentially Smoothed Average	.967	.033

A similar analysis was applied to helicopter instructional flying, yielding

$$HF(5,6) = 13.6 * (HCI + HRI)$$

where HCI is the number of helicopter certificates issued during the year and HRI is the number of helicopter ratings issued.

In order to determine the demand for instructional aircraft, the concept of a desired-aircraft-utilization-rate was used to convert the annual demand for hours flown into an equivalent demand for active fleet size. Historical values for the desired-aircraft-utilization-rates were developed and regressed against fixed costs, total costs, and the gross national product. Only the rate corresponding to multi-engine piston displayed any significant correlation,

$$DAUR(5,3) = -303 + 445 * TCP(5,3)$$
$$(9.82)$$

$$R^2 = 0.96$$

$$F_{1,4} = 96.3$$

Values for each of the other two rates were exponentially smoothed,

$$DAUR(5,1) = 408 \text{ hr/aircraft/yr}$$

$$DAUR(5,6) = 253 \text{ hr/aircraft/yr}$$

This structure within the instructional use/single-engine subsegment is illustrated on Figure 21.

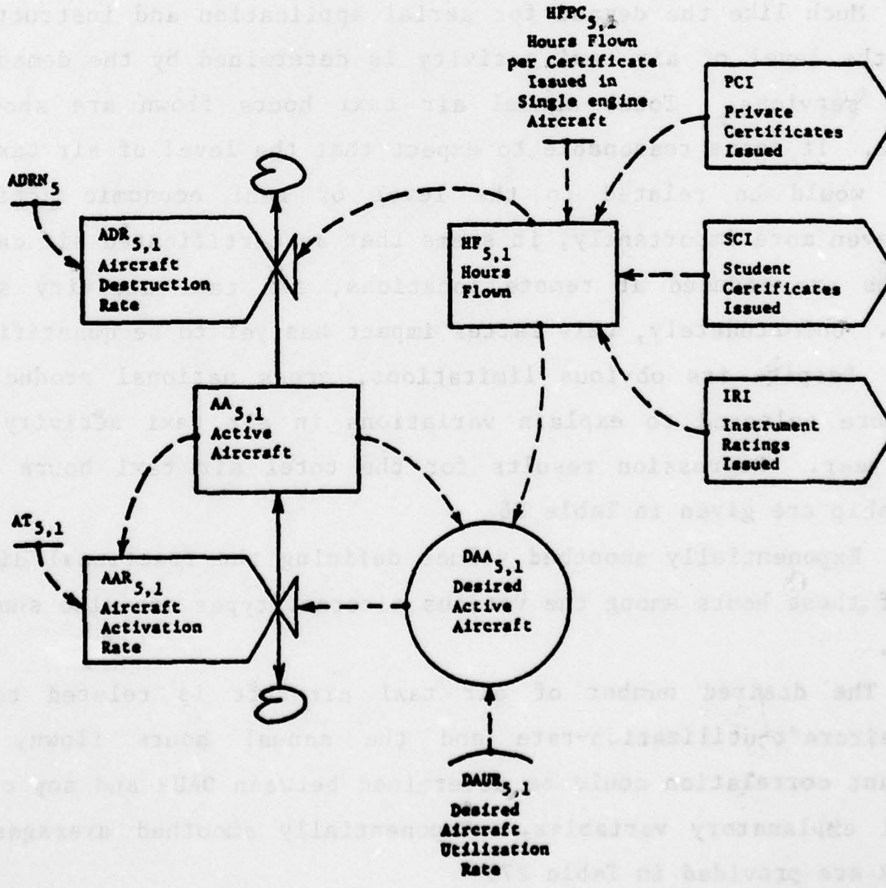

FIGURE 21. STRUCTURE OF THE INSTRUCTIONAL/SINGLE-ENGINE PISTON SUBSEGMENT

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THE GENERAL AVIATION DYNAMICS MODEL VOLUME II. TECHNICAL REPORT--ETC(U)
MAY 79 M A DUFFY, J H MCCREERY DOT-FA77WA-4043
UNCLASSIFIED FAA-AVP-79-8-VOL-2 NL

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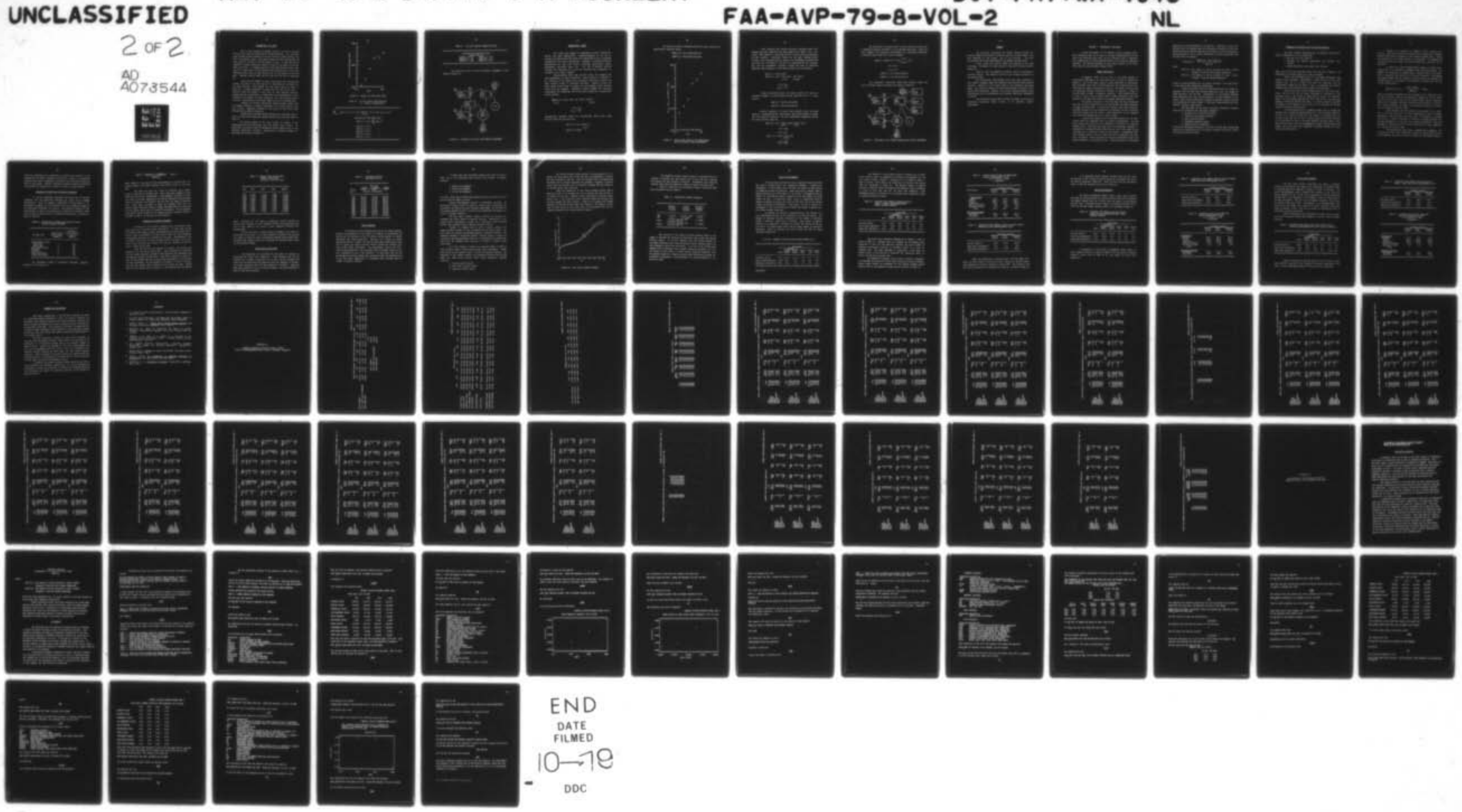

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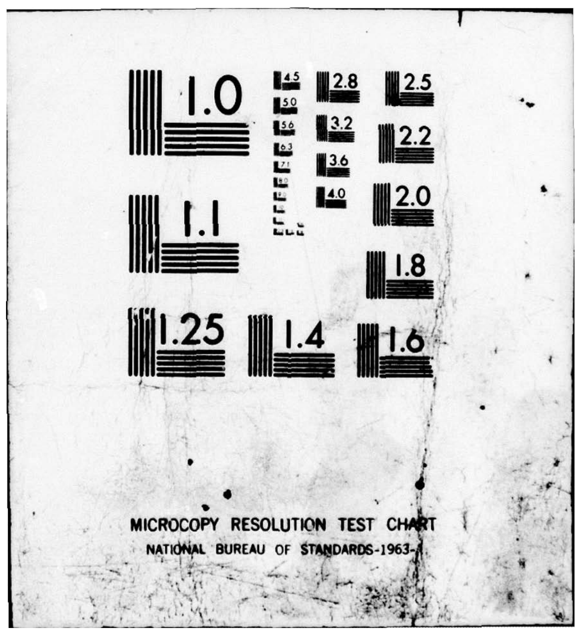
1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

PRIMARY USE - AIR TAXI

The air taxi category of general aviation is meant to include both air taxi operators and commuter airline operators. Air taxi operators provide either scheduled or on-call service in small aircraft "for hire" for specific trips. They operate under CAB Part 298 and FAR 135 which apply to aircraft of 12,500 pounds or less. In 1969 the CAB designated a further distinction within air taxi to be known as the commuter air carrier. A commuter operator flies small aircraft with a maximum of 30 seats and a 7,500 pound payload and performs at least five scheduled round trips per week between two or more points, or carries mail. Commuters operate under CAB Part 298, FAR 135, and at times FAR 121.

Much like the demand for aerial application and instructional flying, the level of air taxi activity is determined by the demand for air taxi services. Total annual air taxi hours flown are shown in Figure 22. It seems reasonable to expect that the level of air taxi activity would be related to the level of real economic activity. Perhaps even more importantly, it seems that as certificated air carrier operations are reduced at remote locations, air taxi activity should increase. Unfortunately, this latter impact has yet to be quantified.

Despite its obvious limitations, gross national product was the measure selected to explain variations in air taxi activity from year to year. Regression results for the total air taxi hours flown relationship are given in Table 26.

Exponentially smoothed values defining the fractional distribution of these hours among the various aircraft types are also shown in Table 24.

The desired number of air taxi aircraft is related to the desired-aircraft-utilization-rate and the annual hours flown. No significant correlation could be determined between DAUR and any of the potential explanatory variables. Exponentially smoothed averages for each DAUR are provided in Table 27.

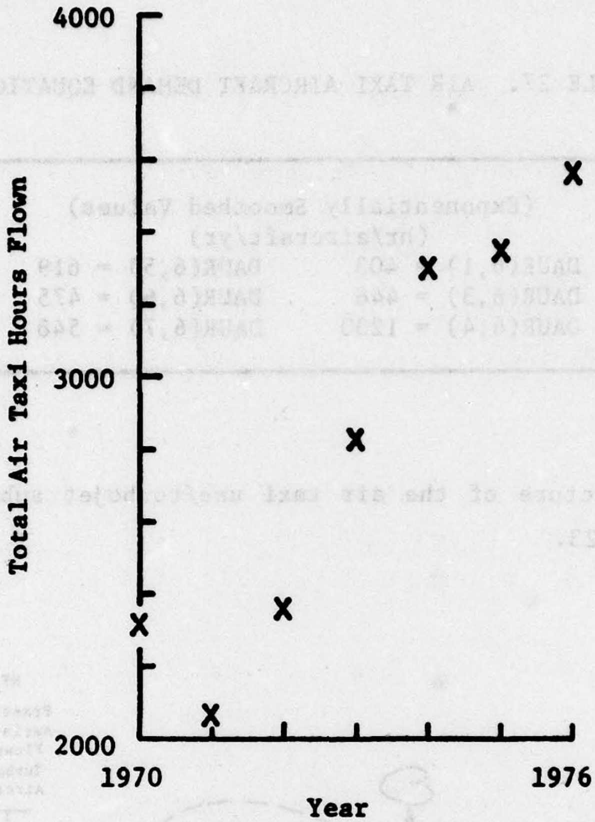

FIGURE 22. ANNUAL AIR TAXI HOURS FLOWN

TABLE 26. AIR TAXI HOURS FLOWN EQUATIONS
(t - values in parenthesis)

$$\sum_{J=1}^{7} HF(6,J) = 2.71 * 10^6 * \underset{(3.44)}{GNP^{3.00}} \quad R^2 = 0.70;\ F_{1,5} = 11.8$$

Exponentially Smoothed Values

$$HF(6,1) = 0.28 * \sum_{J=1}^{7} HF(6,J)$$

$HF(6,3) = 0.40 *$ "

$HF(6,4) = 0.14 *$ "

$HF(6,5) = 0.03 *$ "

$HF(6,6) = 0.03 *$ "

$HF(6,7) = 0.12 *$ "

TABLE 27. AIR TAXI AIRCRAFT DEMAND EQUATIONS

(Exponentially Smoothed Values)
(hr/aircraft/yr)

DAUR(6,1) = 403	DAUR(6,5) = 619
DAUR(6,3) = 448	DAUR(6,6) = 475
DAUR(6,4) = 1230	DAUR(6,7) = 548

The structure of the air taxi use/turbojet subsegment is displayed on Figure 23.

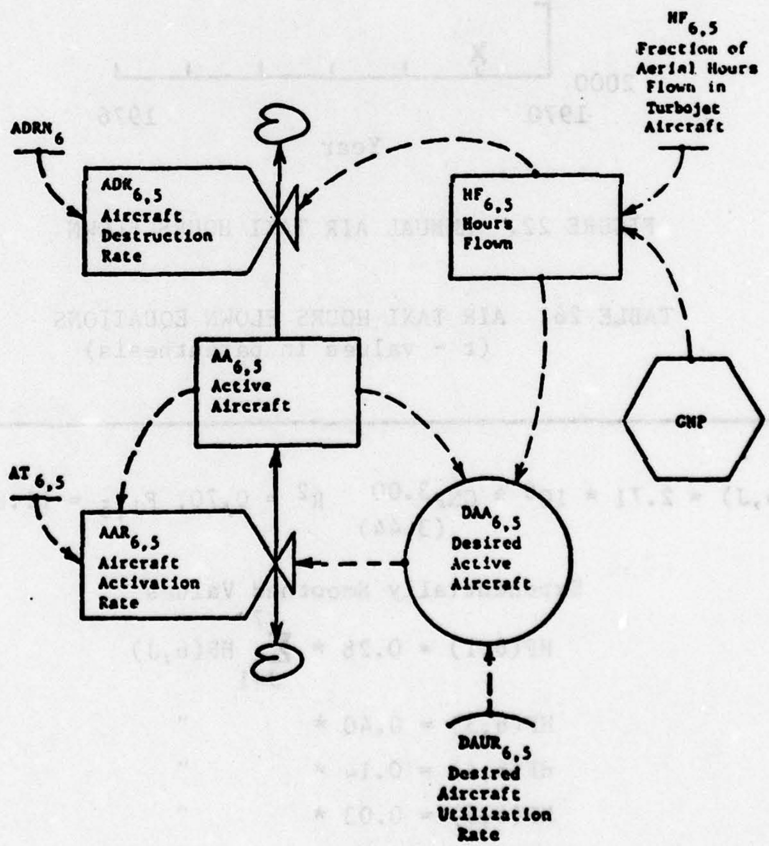

FIGURE 23. STRUCTURE OF THE AIR TAXI/TURBOJET SUBSEGMENT

PRIMARY USE - OTHER

The "other" use category is comprised of rental, industrial/special, and other applications. Industrial/special is any use of aircraft for specialized work allied with industrial activity, excluding transportation and aerial application. Examples of industrial/special applications are pipe line patrol, surveying, advertising, aerial photography, helicopter hoist, etc. Any use of general aviation aircraft, not accounted for in the six previous user categories, is included in the "other" category.

Piston-powered fixed wing aircraft within this category are used predominatly in rental operations. Rental activity is expected to be a function of the active pilot population (potential renters) and their relative levels of individual affluence. Figure 24 shows the total annual hours flown by single and multi-engine piston aircraft within this use category. Regression results suggest the following relationship for estimating the future annual demand for (essentially) rental activity,

$$\sum_{J=1,3} HF(7,J) = 6.50 * (PP + CP + ATP) * DPI^{2.79}$$
$$(2.81)$$

$$R^2 = 0.61$$
$$F_{1,5} = 7.88$$

Exponentially smoothed values for distributing these hours among aircraft types one and three are,

$$HF(7,1) = 0.917 * \sum_{J=1,3} HF(7,J)$$

$$HF(7,3) = 0.083 * \quad ''$$

The desired aircraft utilization rates for these aircraft are exponentially smoothed values,

DAUR(7,1) = 315 hr/aircraft/year

DAUR(7,3) = 258 hr/aircraft/year

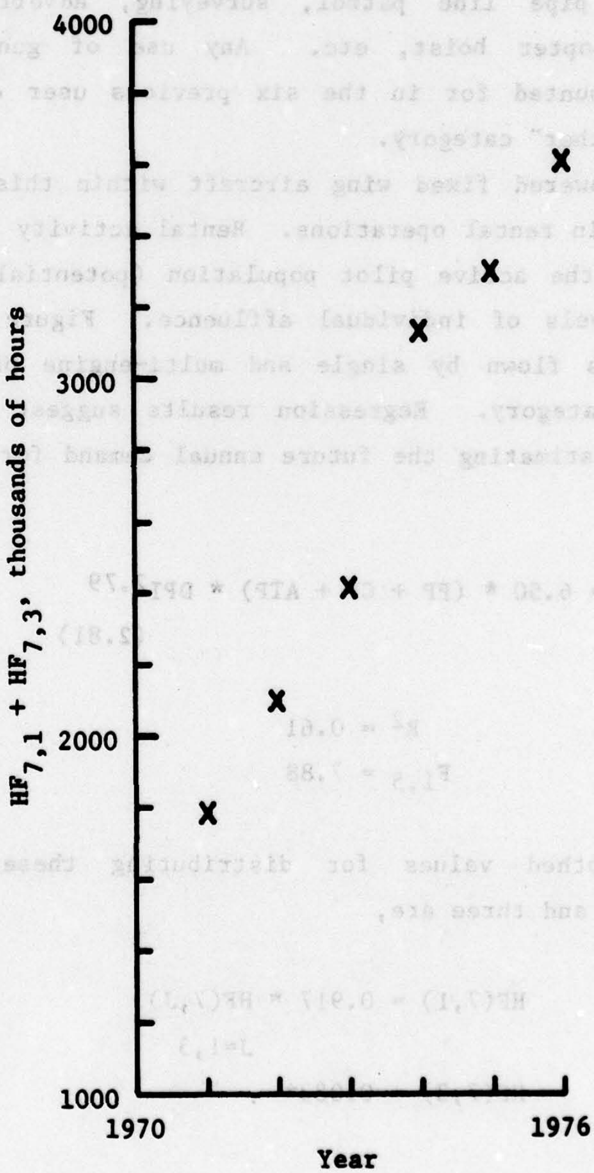

FIGURE 24. ANNUAL HOURS FLOWN IN THE OTHER/SINGLE AND MULTI-ENGINE PISTON SUBSEGMENTS

Most turboprop and turbojet aircraft contained within this category have been reported to be used primarily for "other " use. As a result, their behavior is described similar to that within the corporate aircraft category. Historical values for the goal, desired active aircraft, were regressed directly against the independent variables GNP and fixed cost of ownership. The goal for turboprops did not correlate well with any independent variables, whereas the goal for turbojets displayed some dependence on both GNP and fixed cost of ownership,

$$DAA(7,4) = 169 \text{ aircraft}$$

$$DAA(7,5) = -521 + \underset{(2.77)}{756} * GNP - \underset{(-0.38)}{102} * FC(5)$$

$$R^2 = 0.74$$

$$F_{2,3} = 4.32$$

Annual utilization rates for these aircraft have been essentially constant, at the following values, over the historical scope of data,

$$AUR(7,4) = 332 \text{ hr/aircraft/yr}$$

$$AUR(7,5) = 338 \text{ hr/aircraft/yr}$$

Finally, operators of rotary wing aircraft, which are used mainly in industrial/special applications, were also assumed to behave like the corporate operators. The most significant regression results for these aircraft types are,

$$DAA(7,6) = -230 - \underset{(-3.37)}{887} * FC(6) + \underset{(3.27)}{1667} * GNP$$

$$R^2 = 0.96$$

$$F_{2,3} = 35.4$$

$$DAA(7,7) = -1363 + \underset{(4.34)}{1645} * GNP$$

$$R^2 = 0.82$$

$$F_{1,4} = 18.8$$

The helicopter utilization data for both types were pooled and a regression analysis performed on the resultant data base. These results suggest the following relationships for estimating helicopter utilization rates within the "other" category,

$$AUR(7,J) = AURN(7,J) * VC(J)^{0.415} \quad ; \quad J=6,7$$
$$(2.00)$$

$$R^2 = 0.25$$

$$F_{1,12} = 4.0$$

$$AURN(7,6) = 430 \text{ hr/aircraft/yr}$$

$$AURN(7,7) = 424 \text{ hr/aircraft/yr}$$

The fundamental mechanisms controlling activity within the other use/single engine subsequent are shown on Figure 25.

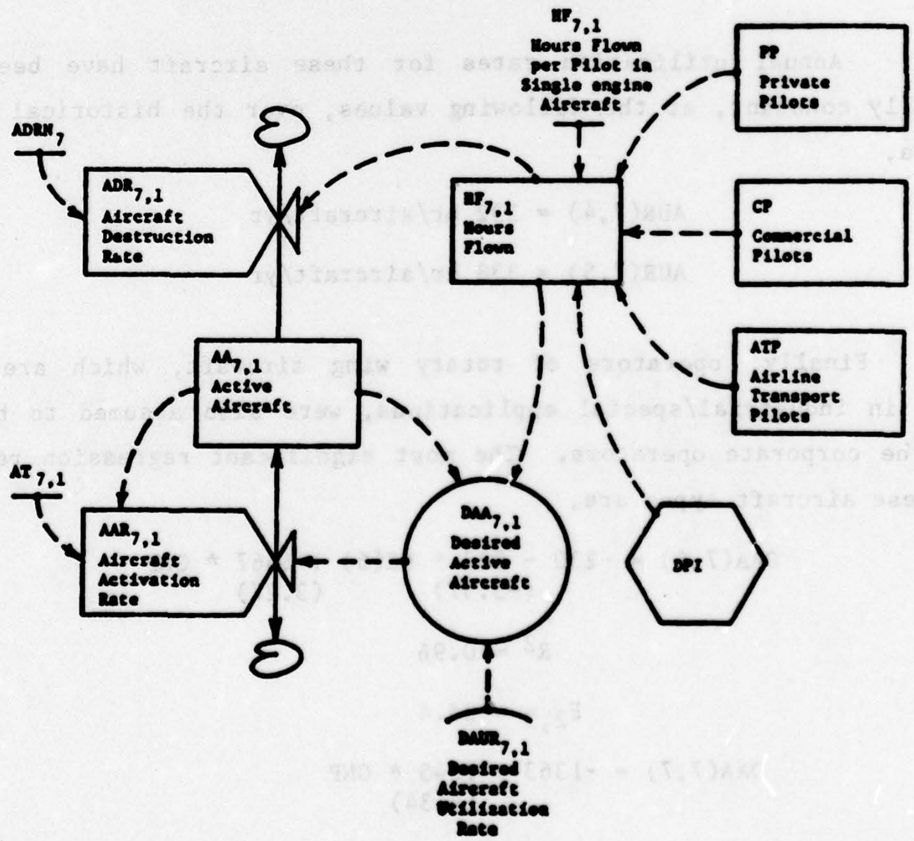

FIGURE 25. STRUCTURE OF THE "OTHER"/SINGLE-ENGINE PISTON SUBSEGMENT

SUMMARY

The structure, describing the dynamic behavior within the aircraft demand and aircraft utilization sectors, has been shown to be very dependent on the primary use of the aircraft. Two main distinctions exist which differentiate the general aviation users.

First, there are aircraft owned and operated by the same individual. The demand for these aircraft is driven by the active pilot population.

There is also the demand for aircraft which are providing a transport service. This demand is driven by the average utilization of the current fleet.

The statistical relationships which have been presented in this chapter recognize these two important distinctions within general aviation. Failure to do so would result in an improperly structured model. Yet, even the validity of these relationships is subject to the severe data limitations. However, as more data become available, these relationships can be reformulated with, perhaps, additional independent variables.

The following chapter shows how the GAD model can be used in evaluating alternative policy actions in an uncertain economic environment.

CHAPTER 5. SIMULATION OF THE MODEL

During development of the General Aviation Dynamics model, many simulations were run in order to increase understanding of its behavior and determine which were its more sensitive parts. Similarly, many combinations of various parameters were tried during the regression analyses. The results presented in this chapter pertain to the "best" model based on data available through CY1976.

MODEL CAPABILITIES

In general, there are two ways to use model results or simulations--individually as projections and in pairs as sensitivity measures. Use of the model simply to make projections is precarious. Many potential users will not understand how the projections were derived and will expect unreasonable accuracy. The model is better used by employing extensive sensitivity analysis to evaluate a range of policies under a range of exogenous conditions. This process can also be used to identify the principal areas of model uncertainty and those portions of the model that deserve the greatest additional research.

The logical structure of the GAD model has been constructed such that relative comparisons can be made between the model forecasts from any two simulations. In particular, during a sensitivity analysis, absolute forecasts for each simulation are available, as well as percent deviations between the two cases. These deviations can be displayed over time either graphically or in tabular format.

A sensitivity analysis can be performed between any two simulations which are compatible with the model's capabilities. All GAD model output data from the first simulation are stored on a separate temporary file. This base case need not be the "baseline" forecast representative of expected future conditions, but can be the result of any consistent set of conditions chosen by the analyst. Intermediate absolute forecast results from this base case can be obtained by the analyst, if desired. After obtaining all required intermediate output, the second simulation is specified and run. Absolute results of the second

simulation are also available to the analyst. Sensitivity results are derived within the program logic by subtracting the results of the first simulation from the second simulation, dividing by the first simulation, and multiplying by 100 to convert differences to percent deviations from the base case; for example,

$$\% \text{ Deviation} = \frac{\left[AA(I,J)_2 - AA(I,J)_1\right] \times 100}{AA(I,J)_1}$$

where,

$AA(I,J)_1$ = the number of active aircraft of type J within category I from the first (base) simulation

$AA(I,J)_2$ = the number of active aircraft of type J within category I from the second simulation.

Values for these parameters are, of course, obtained at the same instant in time during their respective simulations.

Should conditions within the second simulation not change immediately from the base case, percent deviations, until the change becomes effective, will be zero. Furthermore, by continually computing these deviations over time, the non-linearity in model response is preserved. Most previous sensitivity analyses of general aviation activity were predicated on either linear or log-linear sensitivities and their resultant constant elasticities.

The GAD model can be used to evaluate alternative scenarios which can be translated into equivalent changes in

- Variable cost of aircraft operation
- Fixed cost of aircraft ownership
- Gross national product
- Disposable personal income
- Revenue aircraft departures.

As with any forecasting procedure, care must be taken when interpreting results from simulations which are based on parameter values far outside the scope of historical data.

Changing the Variable Cost of Aircraft Operation

The total variable operating cost for general aviation aircraft is comprised of the following items:

- fuel and oil costs ($/hour)
- airframe and avionics maintenance and overhaul cost ($/hour)
- engine maintenance and overhaul cost ($/hour)

These costs vary across aircraft types, but have been assumed to be independent of aircraft usage (i.e., type of flying).

Neither the airframe/avionics nor the engine maintenance and overhaul costs represent, individually, a major portion of the total variable cost; nor is it likely that these two components will be significantly changed in the future. Thus, no capability for directly changing these cost items has been provided in the GAD model.

Fuel and oil costs can be changed directly in one of two ways. First, the fuel tax can be either increased or decreased at any specified time in the future by inserting new values, in cents-per-gallon, for both aviation gas and jet fuel. This can be a one time step change or constantly varying over time. It is also possible to specify the amount of tax change in any one year to be a function of the fuel consumed during the previous year.

A second possibility for changing variable cost is through the specific fuel consumption (gallons/hour) SFC. Any fractional reduction in SFC's for a given aircraft type will result in a proportional reduction in the fuel and oil cost. Current values for SFC are contained in the GAD model for each of the seven different aircraft types. Since each aircraft type is itself the aggregation of many different makes and models, the actual value used represents a weighted average over these various aircraft models.

Finally, it is possible to change the total variable cost directly. The model contains an inflation factor (measured in constant dollars) VCINF which is applied to the current variable costs. Values are provided for the entire period to be simulated. By changing the time series values for VCINF, any future variable cost conditions can be evaluated.

In addition to these straightforward changes in variable operating costs, it is possible to implement other circuitous changes. For example, the imposition of landing fees at towered airports is equivalent to increasing the hourly cost of aircraft operation. By assuming the average flight time per operation and the fraction of operation at towered airports to be constant, the increment to variable cost (in 1972 $) from landing fees is

$$\Delta \text{variable cost}_{ij} = \frac{(.325)\ (LFEE_j)}{2(HPOP_{ij})} * DEFL72$$

where it has been determined that 32.5 percent of all operations occur at towered airports, LFEE is the landing fee imposed (it can be a function of aircraft type), HPOP is the average flight time per operation within the ij category, and DEFL72 converts current dollars to 1972 dollars. These increments are added to the baseline estimates of variable cost and indexed by the 1972 value.

Since variable cost has previously been assumed to be a function of aircraft type only, the most representative value of $HPOP_{ij}$ pertaining to each aircraft type would have to be chosen to preserve this notion. It would be possible to construct a separate variable cost for each subsegment, but this has not yet been incorporated. Thus, the increment to variable cost will be the same within all user categories for a particular aircraft type.

Two possibilities exist when a landing fee is imposed: the increased cost will cause a decrease in activity, some of which will be lost altogether and some of which will divert to non-towered airports.

Since most subsegments are unaffected by variable cost directly, it was assumed that no traffic diversion would occur. Business and corporate users who have shown a dependence on variable cost would most likely behave in this manner. However, additional research should be conducted to determine the tendency for GA users to divert to other airports.

Changing the Fixed Cost of Aircraft Ownership

Of the six components comprising the fixed cost of aircraft ownership, only the annualized investment cost center can be changed individually. Thus, for example, requirements for new safety or environmental equipment can be translated into an incremental change in the annualized investment cost centers. The effective increase of this new equipment is based on the depreciation schedules and residual values used by Aviation Data Services in determining annualized investment as shown in Table 28.

TABLE 28. DEPRECIATION SCHEDULES AND RESIDUAL VALUES FOR NEW AIRCRAFT EQUIPMENT

Aircraft Type J	Depreciation Period (years) DEPREC(J)	Residual Value (percent) of new cost RESID(J)
Single Engine Piston		
Non-Aerial	5	.25
Aerial Appl	5	.25
Multi Engine Piston	5	.25
Turboprop	6	.28
Turbojet	6	.40
Piston Helicopter	5	.25
Turbine Helicopter	5	.30

The incremental change in annualized investment $\Delta AI(J)$, measured in 1972 dollars, is

$$\Delta AI(J) = \frac{DELTA(J) * (1-RESID(J))}{DEPREC(J)} * DEFL72$$

where DELTA(J) is the price of the new equipment for aircraft type J in current dollars, and DEFL72 deflates this current value to 1972 dollars.

The fixed cost also has a built in inflation factor FCINF, similar to the one for variable cost. Thus, any future changes in total fixed cost are easily accommodated. Since dramatic increases in fixed cost have not yet been experienced, the current behavioral relationships cannot be expected to extrapolate very far past the range of available data. Thus, small increases in fixed cost probably will have the minimal impact indicated; however, larger increases which are evaluated with the present model must be carefully interpreted. If new equipment requirements become mandatory, the general aviation response should be analyzed to update the appropriate relationships.

Changing the Economic Variables

Evaluation of any potential federal policy action must itself take place in an uncertain future environment. In order that the FAA can evaluate the impact of their anticipated policy actions under alternative future environments, the time series values for each exogenous socioeconomic variable can be modified by the user. Nevertheless, a set of default values must be self-contained within the model; in the absence of any modified data inputs, the national economic projections shown in Table 29 are used.

Both GNP and DPI are measured in constant 1972 dollars and indexed to the 1972 value (1972=1.000). These estimates are consistent with the values used most recently by the FAA which were developed from the Wharton national economy model. Real GNP is expected to grow at a rate of 3.66 percent per year through 1982, decreasing to 3.34 percent per year afterwards. DPI was assumed to increase at a rate of 3.12 percent per year through 1982, followed by 3.25 percent per year. DEFL72 which is the current dollar deflator is also derived from the Wharton

TABLE 29. DEFAULT VALUE FOR NATIONAL ECONOMIC PROJECTIONS (Indexed to the 1972 Value)

Year	GNP	DPI	RAD	DEFL72
1977	1.1376	1.1339	1.036	0.7072
1978	1.1793	1.1693	1.088	0.6678
1979	1.2224	1.2058	1.143	0.6306
1980	1.2672	1.2434	1.200	0.5955
1981	1.3136	1.2822	1.260	0.5624
1982	1.3617	1.3222	1.323	0.5311
1983	1.4071	1.3652	1.390	0.5066
1984	1.4541	1.4095	1.460	0.4832
1985	1.5026	1.4533	1.533	0.4609
1986	1.5527	1.5026	1.610	0.4396

model. Estimates for the number of commercial revenue aircraft departures RAD (indexed to 1972) represent current FAA expectations and are, in fact, based on the output of their commercial airline forecasting model.

Any of the values in Table 29 can be changed to any other desired value in any year. It is also possible to eliminate the entering of a series of values by simply entering the desired annual growth rate. The model will compound this rate to develop the required annual levels of the economic variable.

Miscellaneous Input Data

The estimated U.S. population by age group is required in projecting the active pilot population. Since everyone that will be eligible for a student certificate by the year 1986 has already been born, only the death rates and migratory rates are important in projecting current population into the age categories of interest. Using the same rates applied by the U.S. Bureau of Census, the values provided in Table 30 have been estimated.

TABLE 30. PROJECTED RESIDENT POPULATION OF U.S.

	Age Group		
	POP(1)	POP(2)	POP(3)
As of July 1	16-24	25-34	35+
	Numbers in Thousands		
1977	36,173	31,803	88,895
1978	35,990	32,123	89,117
1979	35,575	32,745	88,811
1980	34,814	33,388	88,911
1981	34,034	34,194	88,716
1982	32,812	34,227	89,581
1983	31,490	34,501	89,293
1984	30,196	34,791	89,222
1985	28,922	35,099	89,220
1986	27,728	35,213	89,342
1987	26,900	35,115	89,290

Policy Analysis

The Federal Aviation Administration has as its prime responsibilities the regulation of air commerce to promote its development and safety, and the operation of the air traffic control system in a manner consistent with those objectives. Recently, as a result of several spectacular mid-air crashes, the FAA has come under strong public pressure to revamp the current national aviation system and, thereby, provide a safer flight environment. Not surprisingly, most of the criticism has been directed at the increased level of general aviation activity, especially at major hub airports. On the other side are the strong general aviation lobbies who continually decry the implementation of any new rules, regulations, or procedures that infringe upon the "rights" of general aviation.

It seems that this nationwide debate could lead the FAA to adopt one of the following three policies with respect to general aviation:

- passive encouragement
- active encouragement
- active discouragement

Of course, under their present congressional charter, only the first two options could be legally pursued.

Passive encouragement implies a "do-nothing" attitude. By maintaining current levels of taxation, current pilot proficiency requirements, and current aircraft equipment regulations, the FAA would be encouraging general aviation to grow in an uninhibited environment relative to present condition.

The FAA could, however, pursue a policy of actively encouraging the future growth of general aviation. Elimination of all federal taxes, resulting in a lower cost of operation, would certainly promote some increased level of general aviation activity.

Finally, if congress were to yield to public pressure and amend the FAA's charter, it may be possible for the FAA to adopt a future policy of actively discouraging general aviation activity. Two immediate methods of inhibiting general aviation growth, through the now-popular pricing mechanisms, would be to substantially increase fuel taxes and the minimum hours required to obtain a private pilot certificate.

It is not enough to analyze the expected impact of each of these policies under a fixed future socioeconomic environment. Rather they should all be analyzed under a variety of plausible futures. The remainder of this chapter presents the simulation results from the GAD model for these three policies under three alternative economic scenarios:

- limited economic growth
- most likely economic growth
- expansive economic growth

The limited economic growth scenario is characterized by a 2.4 percent per year growth rate in real GNP and a corresponding 2.3 percent per year increase in real DPI. Both the variable cost of operation and the fixed cost of aircraft ownership are assumed to increase 1.0 percent faster than the national rate of inflation through 1983 and thence at 2.0 percent faster than inflation.

Under the assumptions of most likely economic growth, GNP is expected to grow at an average rate of 3.3 percent per year and DPI at an average 3.6 per year. However, rather than impose a constant annual growth rate, a more realistic cyclic variation about the average trend has been assumed for each variable. Figure 26 illustrates the assumed behavior of both GNP and DPI under this scenario. No change in either real variable costs or real fixed costs are anticipated from the assumptions imposed in the limited growth scenario.

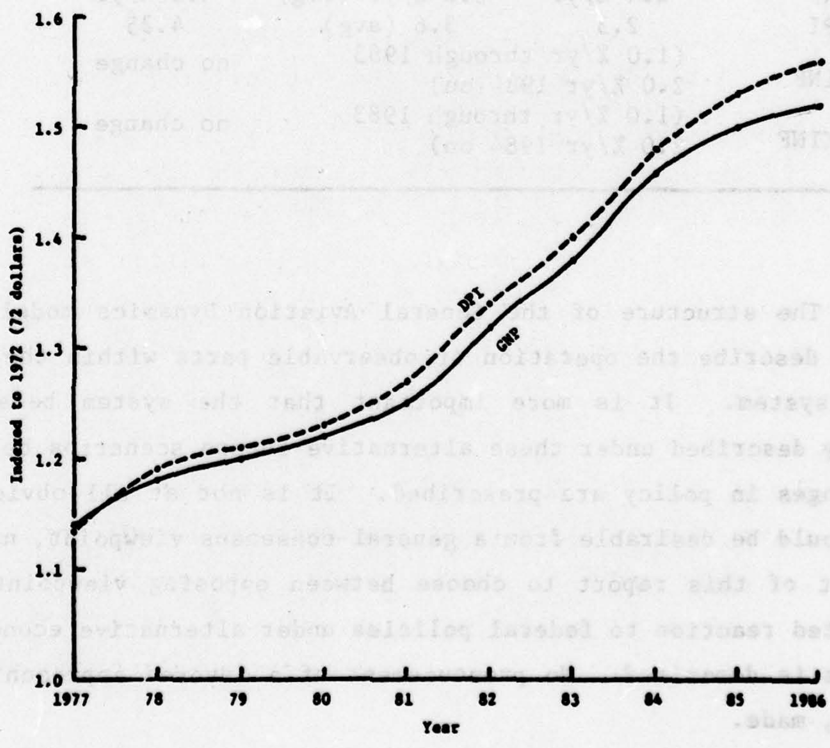

FIGURE 26. MOST LIKELY ECONOMIC SCENARIO

The expansive economic growth scenario is characterized by a constant 4.6 percent per year growth rate in real GNP and a constant 4.35 percent per year increase in real DPI. Furthermore, real fixed and variable costs would be expected to remain at today's relative price.

Table 31 summarizes the anticipated economic conditions under each alternative future scenario.

TABLE 31. COMPARATIVE ECONOMIC SCENARIOS

	Limited Economic Growth	Normal Economic Growth	Expansive Economic Growth
GNP	2.4 %/yr	3.3 %/yr (avg)	4.6 %/yr
DPI	2.3	3.6 (avg)	4.35
VCINF	(1.0 %/yr through 1983 2.0 %/yr 1984 on)		no change
FIXINF	(1.0 %/yr through 1983 2.0 %/yr 1984 on)		no change

The structure of the General Aviation Dynamics model is designed to describe the operation of observable parts within the general aviation system. It is more important that the system behavior be thoroughly described under these alternative future scenarios before any macro-changes in policy are prescribed. It is not at all obvious what changes would be desirable from a general consensus viewpoint, nor is it the intent of this report to choose between opposing viewpoints, only the expected reaction to federal policies under alternative economic environments is described. No pronoucement of a favored approach is, nor should be, made.

Passive Encouragement

The long range planning and policy evaluation done by the FAA must have a reference point for comparative analyses. A passive encouragement, or do-nothing, policy provides the basis for some measure of comparison between alternatives. Under this policy, federal taxes on general aviation fuel would remain at the current 7 cents/gallon and the formula for determining federal registration fee and weight tax would remain the same. No additional taxes, rules, or regulations would be imposed on general aviation; nor would the FAA alter any of the current airmen certification procedures. This policy is one of passive encouragement in that the FAA would not inhibit the growth of general aviation under present conditions.

In meeting its statutory responsibilities, the Federal Aviation Administration must use its resources in an efficient manner. One measure of efficient resource utilization is the number of employees needed to provide a given level of service. With respect to general aviation it is important to estimate the future size and mix of the active fleet, the annual hours flown, and the annual number of operations generated. Table 32 indicates the actual levels for each of these variables during 1976.

TABLE 32. GENERAL AVIATION ACTIVITY LEVELS DURING 1976

		Fixed Wing				
		Piston				
	Total	Single-Engine	Multi-Engine	Turbo-prop	Turbo-jet	Rotor-craft
Aircraft (000's)	175.1	144.9	21.3	2.5	2.5	4.5
Hours Flown* (000,000's	35.8	26.1	5.6	1.3	1.0	1.8
Operations (000,000's)	109.6	87.8	11.3	2.7	1.6	6.2

*Estimated

The Appendix to this volume contains a complete set of model output results under the assumptions of passive encouragement and the most likely economic scenario. Estimates for the expected number of active aircraft, hours flown, and operations by aircraft type during 1986 are reproduced in Table 33. The greatest growth in general aviation is expected within the business use category, which is expected to triple in size over the next ten years (see Appendix). This phenomenal growth is attributed to an increased pilot population within an expanding national economy.

TABLE 33. ESTIMATED 1986 GENERAL AVIATION ACTIVITY LEVELS - PASSIVE ENCOURAGEMENT/MOST LIKELY ECONOMIC SCENARIO

		Fixed Wing				
		Piston				
	Total	Single-Engine	Multi-Engine	Turbo-prop	Turbo-jet	Rotor-craft
Aircraft (000's)	379.7	306.0	53.3	5.6	5.1	9.6
Hours Flown (000,000's)	75.3	53.8	13.6	2.1	2.4	3.5
Operations (000,000's)	210.8	163.0	27.3	5.4	3.9	11.2

The active pilot population expected as of January 1, 1987 is shown on Table 34. Although there is a tendency for the student pilot population to level out and eventually decline, the active number of advanced certificates continues to increase, albeit at an ever decreasing rate. The major detriment to sustaining a high number of student starts is the decline in available U.S. population which, of course, the FAA has no control over.

For comparative purposes, and in order to provide a comprehensive treatment of each policy option under alternative future economics, similar model results are presented for the limited economic growth scenario and for the expansive economic growth scenario in Table 35.

TABLE 34. ACTIVE PILOTS BY TYPE OF CERTIFICATE-PASSIVE ENCOURAGEMENT POLICY as of January 1, 1987 (thousands)

Certificates	Economic Scenario: Limited Growth	Most Likely	Expansive Growth
Certificates			
Student	165.3	174.9	210.4
Private	368.7	376.0	384.1
Commercial	226.7	227.4	250.5
Airline Transport	74.4	74.4	75.7
Helicopter (only)	2.0	2.0	3.3
Total	837.1	854.7	924.0
Additional Ratings			
Instrument	329.3	330.2	355.1
Helicopter	36.1	36.1	36.8

TABLE 35. COMPARATIVE 1986 GENERAL AVIATION ACTIVITY LEVELS UNDER THE PASSIVE ENCOURAGEMENT POLICY

	Economic Scenario: Limited Growth	Most Likely	Expansive Growth
Aircraft (000's)	318.5	379.7	459.6
Hours Flown (000,000's)	62.5	75.3	95.0
Operations (000,000's)	177.0	210.8	261.6

Under the assumption of limited growth, the GAD model estimates an active fleet of 318,500 aircraft, flying 62.5 million hours, and conducting 177 million operations during 1986. The growth in the active pilot population is retarded only slightly, as shown in Table 32.

In an expansive growth economy, 459,600 active aircraft would be expected by 1986, flying 95 million hours and responsible for nearly 262 million operations (Table 35). These aircraft would be serving the needs of some 924 thousand active pilots (Table 34).

Active Encouragement

An easily implemented federal policy which would actively encourage the continued growth of general aviation would be to eliminate the present federal fuel tax of seven cents per gallon on all general aviation fuel. Simulated results, based on eliminating the fuel tax in 1979, for the most likely economic scenario are provided in Table 36.

TABLE 36. ESTIMATED 1986 GENERAL AVIATION ACTIVITY LEVELS-ACTIVE ENCOURAGEMENT/MOST LIKELY ECONOMIC SCENARIO

		Fixed Wing				
		Piston				
	Total	Single-Engine	Multi-Engine	Turbo-prop	Turbo-jet	Rotor-craft
Aircraft (000's)	384.7	310.5	53.8	5.6	5.1	9.7
Hours Flown (000,000's)	76.3	54.6	13.7	2.1	2.4	3.5
Operations (000,000's)	214.0	165.8	27.6	5.4	3.9	11.3

A comparison of this active encouragement policy under all three economic scenarios is shown in Table 37 for the levels of general aviation activity and in Table 38 for the levels of active pilot population.

TABLE 37. COMPARATIVE 1986 GENERAL AVIATION ACTIVITY LEVELS UNDER THE ACTIVE ENCOURAGEMENT POLICY

	Economic Scenario		
	Limited Growth	Most Likely	Expansive Growth
Aircraft (000's)	322.6	384.7	466.3
Hours Flown (000,000's)	63.4	76.3	96.4
Operations (000,000's)	179.8	214.0	266.1

TABLE 38. ESTIMATED ACTIVE PILOTS UNDER THE ACTIVE ENCOURAGEMENT POLICY as of January 1, 1987 (thousands)

	Economic Scenario		
	Limited Growth	Most Likely	Expansive Growth
Certificates			
Student	170.4	180.3	217.8
Private	371.9	379.3	387.4
Commercial	234.0	234.8	260.0
Airline Transport	75.0	75.0	76.4
Helicopter (only)	2.2	2.2	3.7
Total			
Additional Ratings			
Instrument	337.4	338.4	365.5
Helicopter	36.4	36.4	37.2

Active Discouragement

The FAA could actively discourage the growth of general aviation by increasing fuel taxes and by increasing the minimum number of instructional hours required to obtain a private certificate. The active discouragement policy evaluated here assumes a five cents per gallon increase in fuel tax per year, beginning in 1979 and continuing through 1983. This represents a net increase in fuel tax from seven to 32 cents per gallon. The fuel tax is assumed to remain at the 32 cents per gallon level after 1983. Furthermore, it is assumed under this policy, that the flight hours required to obtain a private certificate would be doubled in 1979. This has the effect of doubling the cost of acquiring a private certificate.

Table 39 illustrates the 1986 general aviation activity levels that would be expected under these changes in the most likely economic scenario.

TABLE 39. ESTIMATED 1986 GENERAL AVIATION ACTIVITY LEVELS - ACTIVE DISCOURAGEMENT/MOST LIKELY ECONOMIC SCENARIO

	Fixed Wing					
		Piston				
	Total	Single-Engine	Multi-Engine	Turbo-prop	Turbo-jet	Rotor-craft
Aircraft (000's)	290.8	226.2	44.4	5.6	5.1	9.5
Hours Flown (000,000's)	58.9	39.5	11.6	2.0	2.3	3.5
Operations (000,000's)	157.4	114.2	23.31	5.3	3.8	11.0

Table 40 illustrates the wide range in total activity levels that would be expected in the alternative economic environments, and Table 41 shows corresponding data for the active pilot population.

TABLE 40. COMPARATIVE 1986 GENERAL AVIATION ACTIVITY LEVELS - UNDER THE ACTIVE ENCOURAGEMENT POLICY

	Economic Scenario		
	Limited Growth	Most Likely	Expansive Growth
Aircraft (000's)	244.4	290.8	347.5
Hours Flown (000,000's)	49.0	58.9	73.7
Operations (000,000's)	131.7	157.4	193.6

TABLE 41. ESTIMATED ACTIVE PILOTS UNDER THE ACTIVE DISCOURAGEMENT POLICY as of January 1, 1987 (thousands)

	Economic Scenario		
	Limited Growth	Most Likely	Expansive Growth
Certificates			
Student	62.0	65.9	78.3
Private	215.0	218.0	217.6
Commercial	183.5	183.7	195.3
Airline Transport	71.9	71.9	72.7
Helicopter (only)	1.5	1.5	2.4
Total			
Additional Ratings			
Instrument	273.4	273.7	286.2
Helicopter	34.6	34.6	35.0

SUMMARY AND CONCLUSIONS

This policy application of the GAD model provides the basis for supporting several conclusions. First, the results reinforce the hypothesis that a general aviation model should explicity recognize the mutual interactions between all sectors of general aviation and external socioeconomic conditions. This particular conclusion is supported most strongly by model experiments which demonstrate that significant changes occurring in the pilot sector have equally significant ramifications in the aircraft sector.

The most significant finding from these policy analyses, is that the future of general aviation is more likely to be dictated by the performance of the national economy than by any possible changes in federal policy. Between the extremes of the active discouragement and the active encouragement policies, there is only a net difference of 95 thousand aircraft expected by 1986 (under the most likely economic scenario). However, between the economic extremes of limited growth and expansive growth, a net difference of 140,000 aircraft would be expected by 1986 (under the passive encouragement policy).

In summary, the General Aviation Dynamics model can be used in many different, yet important, applications. As its use becomes more widespread, it should be accepted as a standard for producing forecasts and evaluating the impact of regulatory policies on the future of general aviation.

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APPENDIX A

GENERAL AVIATION DYNAMICS MODEL OUTPUT
PASSIVE ENCOURAGEMENT/MOST LIKELY ECONOMIC SCENARIO

TOTALS FOR AIRCRAFT, HOURS FLOWN AND OPERATIONS, 1977 TO 1987

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
TOTAL AIRCRAFT	175,130	184,633	201,114	215,740	228,036	242,947	266,532	294,001	327,164	357,622
TOTAL HOURS FLOWN (THOUSANDS)	35,850	36,932	40,560	42,896	45,162	48,238	53,646	59,025	66,312	71,641
TOTAL OPERATIONS	109,616	111,581	121,260	127,404	133,376	141,621	155,785	169,530	188,128	201,560

	1987
TOTAL AIRCRAFT	379,702
TOTAL HOURS FLOWN (THOUSANDS)	75,337
TOTAL OPERATIONS	210,775

PILOT DATA, 1977 TO 1987

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
STUDENT PILOTS	188,801	183,794	183,654	183,176	182,384	182,471	183,122	181,626	180,463	178,248	174,891
PRIVATE PILOTS	309,805	323,821	335,104	344,608	352,437	358,682	363,763	368,310	371,781	374,399	375,960
COMMERCIAL PILOTS	187,881	189,699	192,068	195,342	199,209	203,591	208,388	213,191	217,972	222,780	227,353
AIR TRANSPORT PILOTS	45,872	47,784	50,879	53,766	56,656	59,549	62,466	65,414	68,401	71,413	74,447
PILOT SUBTOTAL	730,679	745,898	761,705	776,891	790,685	804,292	817,739	828,541	838,617	846,759	852,650
HELICOPTER PILOTS	4,804	4,333	3,940	3,608	3,322	3,074	2,855	2,628	2,403	2,187	1,983
TOTAL PILOTS	735,483	749,431	765,645	780,499	794,007	807,366	820,595	831,169	841,020	848,946	854,634
INSTRUMENT RATINGS	211,364	221,497	232,437	243,969	255,978	268,368	281,046	293,596	306,000	318,202	330,169
HELICOPTER RATINGS	23,012	24,395	25,739	27,052	28,347	29,633	30,916	32,203	33,493	34,786	36,081
TOTAL HELIC RATINGS	27,816	28,728	29,679	30,659	31,669	32,706	33,771	34,831	35,896	36,973	38,064

ECONOMIC DATA, 1977 TO 1987

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
DPI (1972 $, 1972=1)	1.1339	1.1900	1.2100	1.2300	1.2700	1.3400	1.4000	1.4800	1.5300	1.5600	1.6000
GNP (1972 $, 1972=1)	1.1376	1.1800	1.2000	1.2200	1.2500	1.3200	1.3800	1.4600	1.5000	1.5200	1.6000
RAD (1972 $, 1972=1)	1.0360	1.0880	1.1430	1.2000	1.2600	1.3230	1.3900	1.4600	1.5330	1.6100	1.6910

VARIABLE COST ($/YR), (1972 $, 1972=1)

	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
1977	1.138	1.194	1.194	1.092	1.172	1.222	1.174
1978	1.150	1.206	1.206	1.103	1.183	1.234	1.185
1979	1.161	1.217	1.217	1.114	1.195	1.246	1.197
1980	1.172	1.229	1.229	1.125	1.206	1.258	1.208
1981	1.183	1.241	1.241	1.135	1.218	1.270	1.220
1982	1.195	1.253	1.253	1.146	1.230	1.283	1.232
1983	1.217	1.277	1.277	1.168	1.253	1.307	1.255
1984	1.240	1.300	1.300	1.189	1.276	1.331	1.278
1985	1.262	1.324	1.324	1.211	1.299	1.355	1.301
1986	1.285	1.347	1.347	1.233	1.322	1.379	1.325
1987	1.307	1.371	1.371	1.254	1.346	1.404	1.348

ACTIVE AIRCRAFT BY PRIMARY USE, DURING PREVIOUS YEAR AS REPORTED ON JANUARY 1 OF DESIGNATED YEAR

1977

	TOTAL	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
TOTAL	175,130	138,057	6,824	21,320	2,486	1,938	2,753	1,752
BUSINESS	37,349	28,484	0	8,441	0	0	424	0
CORPORATE	10,283	1,612	0	4,570	1,975	1,582	0	544
PERSONAL	85,110	81,462	0	3,188	0	0	460	0
AERIAL	7,757	0	6,824	354	0	0	579	0
INSTRUCTIONAL	13,026	12,177	0	568	0	0	281	0
AIR TAXI	6,789	2,327	0	2,964	347	177	182	792
OTHER	14,816	11,995	0	1,235	164	179	827	416

1978

	TOTAL	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
TOTAL	184,633	144,716	7,576	22,528	2,696	2,292	2,740	2,086
BUSINESS	41,898	32,189	0	9,207	0	0	502	0
CORPORATE	11,276	1,747	0	4,961	2,196	1,794	0	577
PERSONAL	87,017	83,434	0	3,244	0	0	339	0
AERIAL	8,560	0	7,576	396	0	0	588	0
INSTRUCTIONAL	12,449	11,636	0	531	0	0	282	0
AIR TAXI	7,167	2,323	0	3,057	334	279	160	1,014
OTHER	16,266	13,388	0	1,130	165	219	869	495

1979

	TOTAL	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
TOTAL	201,114	157,615	7,841	25,003	3,051	2,469	3,046	2,088
BUSINESS	47,524	36,693	0	10,255	0	0	576	0
CORPORATE	12,370	1,931	0	5,303	2,444	2,030	0	663
PERSONAL	94,843	90,870	0	3,611	0	0	362	0
AERIAL	8,834	0	7,841	370	0	0	623	0
INSTRUCTIONAL	12,059	11,371	0	382	0	0	306	0
AIR TAXI	8,018	2,747	0	3,527	442	191	249	863
OTHER	17,465	14,003	0	1,555	165	249	930	562

ACTIVE AIRCRAFT BY PRIMARY USE, DURING PREVIOUS YEAR AS REPORTED ON JANUARY 1 OF DESIGNATED YEAR

1980

	TOTAL	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
TOTAL	215,740	168,882	8,283	27,186	3,219	2,704	3,206	2,260
BUSINESS	52,463	40,573	0	11,277	0	0	634	0
CORPORATE	13,077	2,016	0	5,568	2,561	2,229	0	703
PERSONAL	99,364	95,177	0	3,809	0	0	378	0
AERIAL	9,332	0	8,283	391	0	0	658	0
INSTRUCTIONAL	12,162	11,493	0	365	0	0	304	0
AIR TAXI	8,954	3,067	0	3,938	494	213	278	964
OTHER	20,368	16,556	0	1,838	165	262	954	593

1981

	TOTAL	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
TOTAL	228,036	178,403	8,712	28,928	3,363	2,904	3,344	2,382
BUSINESS	57,164	44,191	0	12,290	0	0	683	0
CORPORATE	13,725	2,103	0	5,795	2,679	2,405	0	743
PERSONAL	103,822	99,419	0	4,008	0	0	395	0
AERIAL	9,816	0	8,712	412	0	0	692	0
INSTRUCTIONAL	12,236	11,631	0	302	0	0	302	0
AIR TAXI	9,418	3,226	0	4,142	519	224	293	1,014
OTHER	21,857	17,833	0	1,979	165	276	979	625

1982

	TOTAL	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
TOTAL	242,947	190,085	9,127	30,985	3,565	3,120	3,523	2,542
BUSINESS	62,492	48,313	0	13,429	0	0	750	0
CORPORATE	14,535	2,233	0	6,855	2,855	2,588	0	804
PERSONAL	110,007	105,285	0	4,305	0	0	418	0
AERIAL	10,283	0	9,127	431	0	0	725	0
INSTRUCTIONAL	12,335	11,741	0	291	0	0	302	0
AIR TAXI	9,894	3,389	0	4,351	545	235	308	1,065
OTHER	23,482	19,124	0	2,123	165	297	1,020	673

ACTIVE AIRCRAFT BY PRIMARY USE, DURING PREVIOUS YEAR AS REPORTED ON JANUARY 1 OF DESIGNATED YEAR

1983

	TOTAL	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
TOTAL	266,532	208,519	9,526	34,261	4,015	3,468	3,866	2,877
BUSINESS	71,508	55,393	0	15,214	0	0	900	0
CORPORATE	16,149	2,537	0	6,533	3,265	2,867	0	946
PERSONAL	118,966	113,755	0	4,763	0	0	446	0
AERIAL	10,733	0	9,526	450	0	0	757	0
INSTRUCTIONAL	12,426	11,867	0	257	0	0	303	0
AIR TAXI	10,631	3,643	0	4,676	585	253	331	1,144
OTHER	26,120	21,324	0	2,368	165	348	1,128	787

1984

	TOTAL	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
TOTAL	294,001	229,549	9,909	38,658	4,470	3,875	4,244	3,296
BUSINESS	82,265	63,804	0	17,384	0	0	1,077	0
CORPORATE	17,735	2,797	0	7,069	3,615	3,187	0	1,067
PERSONAL	127,104	121,444	0	5,183	0	0	477	0
AERIAL	11,165	0	9,909	468	0	0	787	0
INSTRUCTIONAL	12,565	12,013	0	248	0	0	305	0
AIR TAXI	12,523	4,291	0	5,508	689	298	389	1,348
OTHER	30,644	25,201	0	2,798	165	390	1,209	881

1985

	TOTAL	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
TOTAL	327,164	255,896	10,276	43,922	5,035	4,365	4,691	3,778
BUSINESS	96,551	75,011	0	20,249	0	0	1,291	0
CORPORATE	19,763	3,143	0	7,729	4,083	3,578	0	1,229
PERSONAL	137,345	131,100	0	5,734	0	0	511	0
AERIAL	11,578	0	10,276	485	0	0	816	0
INSTRUCTIONAL	12,554	12,028	0	222	0	0	304	0
AIR TAXI	14,304	4,901	0	6,292	787	348	445	1,539
OTHER	35,069	28,912	0	3,211	165	447	1,324	1,018

ACTIVE AIRCRAFT BY PRIMARY USE, DURING PREVIOUS YEAR AS REPORTED ON JANUARY 1 OF DESIGNATED YEAR

1986

	TOTAL	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
TOTAL	357,622	278,217	10,626	49,331	5,416	4,802	5,025	4,205
BUSINESS	109,210	84,788	0	22,983	0	0	1,439	0
CORPORATE	21,115	3,315	0	8,248	4,317	3,925	0	1,309
PERSONAL	144,661	137,997	0	6,124	0	0	539	0
AERIAL	11,972	0	10,626	502	0	0	844	0
INSTRUCTIONAL	12,544	12,028	0	211	0	0	304	0
AIR TAXI	16,955	5,809	0	7,457	934	403	527	1,825
OTHER	41,166	34,280	0	3,805	165	474	1,371	1,071

1987

	TOTAL	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
TOTAL	379,702	295,055	10,958	53,313	5,614	5,121	5,209	4,431
BUSINESS	119,802	92,209	0	25,282	0	0	1,511	0
CORPORATE	21,980	3,401	0	8,597	4,435	4,197	0	1,349
PERSONAL	149,947	142,985	0	6,399	0	0	563	0
AERIAL	12,346	0	10,958	518	0	0	870	0
INSTRUCTIONAL	12,482	11,986	0	191	0	0	305	0
AIR TAXI	18,395	6,301	0	8,090	1,014	438	572	1,980
OTHER	45,549	38,172	0	4,237	165	486	1,387	1,102

FUEL CONSUMED (MILLION GALLONS) DURING PREVIOUS YEAR, AS REPORTED ON JANUARY 1 OF DESIGNATED YEAR

	TOTAL	AV GAS	JET FUEL
1977	0	0	0
1978	1,043	524	519
1979	1,154	576	578
1980	1,230	610	619
1981	1,300	644	656
1982	1,389	689	699
1983	1,550	768	782
1984	1,712	848	865
1985	1,929	956	973
1986	2,087	1,037	1,051
1987	2,197	1,093	1,103

HOURS FLOWN (THOUSANDS) DURING PREVIOUS YEAR AS REPORTED ON JANUARY 1 OF DESIGNATED YEAR

1977

	TOTAL	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
TOTAL	35,850	24,142	2,002	5,610	1,327	1,000	786	983
BUSINESS	6,418	4,664	0	1,664	0	0	90	0
CORPORATE	3,663	337	0	1,518	858	735	0	215
PERSONAL	9,622	9,074	0	516	0	0	32	0
AERIAL	2,227	0	2,002	64	0	0	161	0
INSTRUCTIONAL	5,042	4,805	0	165	0	0	72	0
AIR TAXI	3,566	945	0	1,384	425	174	77	561
OTHER	5,312	4,317	0	299	44	91	354	207

1978

	TOTAL	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
TOTAL	36,932	24,433	2,073	6,104	1,470	1,058	876	917
BUSINESS	6,889	5,021	0	1,774	0	0	94	0
CORPORATE	3,980	391	0	1,654	857	864	0	214
PERSONAL	9,137	8,677	0	451	0	0	8	0
AERIAL	2,303	0	2,073	60	0	0	170	0
INSTRUCTIONAL	4,936	4,697	0	160	0	0	78	0
AIR TAXI	3,990	1,117	0	1,596	559	120	120	479
OTHER	5,698	4,529	0	410	55	74	406	224

1979

	TOTAL	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
TOTAL	40,560	26,944	2,190	6,721	1,545	1,192	936	1,031
BUSINESS	7,794	5,724	0	1,970	0	0	100	0
CORPORATE	4,275	432	0	1,759	867	975	0	241
PERSONAL	9,961	9,451	0	502	0	0	9	0
AERIAL	2,433	0	2,190	63	0	0	180	0
INSTRUCTIONAL	4,987	4,748	0	162	0	0	77	0
AIR TAXI	4,453	1,247	0	1,781	623	134	134	534
OTHER	6,657	5,342	0	484	55	84	437	256

HOURS FLOWN (THOUSANDS) DURING PREVIOUS YEAR AS REPORTED ON JANUARY 1 OF DESIGNATED YEAR

1980

	TOTAL	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
TOTAL	42,896	28,549	2,303	7,154	1,536	1,296	972	1,066
BUSINESS	8,596	6,329	0	2,161	0	0	106	0
CORPORATE	4,437	452	0	1,839	826	1,067	0	253
PERSONAL	10,437	9,898	0	529	0	0	9	0
AERIAL	2,559	0	2,303	67	0	0	189	0
INSTRUCTIONAL	5,046	4,805	0	164	0	0	77	0
AIR TAXI	4,683	1,311	0	1,873	656	140	140	562
OTHER	7,138	5,754	0	521	55	89	449	271

1981

	TOTAL	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
TOTAL	45,162	30,109	2,412	7,574	1,530	1,389	1,006	1,142
BUSINESS	9,353	6,894	0	2,349	0	0	110	0
CORPORATE	4,575	471	0	1,905	786	1,148	0	264
PERSONAL	10,906	10,340	0	557	0	0	10	0
AERIAL	2,680	0	2,412	70	0	0	198	0
INSTRUCTIONAL	5,093	4,850	0	166	0	0	77	0
AIR TAXI	4,921	1,378	0	1,968	689	148	148	591
OTHER	7,633	6,176	0	559	55	93	463	287

1982

	TOTAL	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
TOTAL	48,238	32,268	2,518	8,122	1,558	1,492	1,053	1,227
BUSINESS	10,212	7,537	0	2,560	0	0	115	0
CORPORATE	4,759	500	0	1,982	763	1,232	0	282
PERSONAL	11,558	10,950	0	598	0	0	10	0
AERIAL	2,797	0	2,518	73	0	0	207	0
INSTRUCTIONAL	5,147	4,902	0	167	0	0	77	0
AIR TAXI	5,293	1,482	0	2,117	741	159	159	635
OTHER	8,471	6,897	0	624	55	100	485	310

HOURS FLOWN (THOUSANDS) DURING PREVIOUS YEAR AS REPORTED ON JANUARY 1 OF DESIGNATED YEAR

1983

	TOTAL	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
TOTAL	53,646	35,892	2,619	9,160	1,721	1,667	1,153	1,435
BUSINESS	11,658	8,641	0	2,893	0	0	124	0
CORPORATE	5,176	568	0	2,129	794	1,362	0	323
PERSONAL	12,504	11,831	0	662	0	0	11	0
AERIAL	2,910	0	2,619	76	0	0	215	0
INSTRUCTIONAL	5,209	4,962	0	169	0	0	78	0
AIR TAXI	6,233	1,745	0	2,493	873	187	187	748
OTHER	9,956	8,144	0	737	55	118	538	364

1984

	TOTAL	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
TOTAL	59,025	39,524	2,716	10,236	1,835	1,851	1,243	1,620
BUSINESS	13,378	9,953	0	3,289	0	0	135	0
CORPORATE	5,554	626	0	2,284	784	1,505	0	355
PERSONAL	13,363	12,630	0	720	0	0	12	0
AERIAL	3,017	0	2,716	78	0	0	223	0
INSTRUCTIONAL	5,215	4,968	0	170	0	0	78	0
AIR TAXI	7,122	1,994	0	2,849	997	214	214	855
OTHER	11,376	9,351	0	846	55	132	581	411

1985

	TOTAL	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
TOTAL	66,312	44,439	2,808	11,711	2,025	2,086	1,360	1,883
BUSINESS	15,659	11,702	0	3,812	0	0	144	0
CORPORATE	6,048	704	0	2,476	790	1,682	0	396
PERSONAL	14,444	13,634	0	797	0	0	13	0
AERIAL	3,120	0	2,808	81	0	0	231	0
INSTRUCTIONAL	5,215	4,968	0	170	0	0	78	0
AIR TAXI	8,434	2,361	0	3,374	1,181	253	253	1,012
OTHER	13,393	11,078	0	1,002	55	151	641	474

HOURS FLOWN (THOUSANDS) DURING PREVIOUS YEAR AS REPORTED ON JANUARY 1 OF DESIGNATED YEAR

1986

	TOTAL	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
TOTAL	71,641	48,147	2,896	12,803	2,081	2,270	1,425	2,018
BUSINESS	17,686	13,227	0	4,306	0	0	152	0
CORPORATE	6,358	743	0	2,620	746	1,835	0	414
PERSONAL	15,216	14,352	0	851	0	0	13	0
AERIAL	3,217	0	2,896	84	0	0	238	0
INSTRUCTIONAL	5,197	4,950	0	169	0	0	78	0
AIR TAXI	9,146	2,561	0	3,658	1,280	274	274	1,098
OTHER	14,828	12,315	0	1,115	55	160	669	507

1987

	TOTAL	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
TOTAL	75,337	50,770	2,979	13,566	2,072	2,402	1,460	2,088
BUSINESS	19,255	14,385	0	4,715	0	0	156	0
CORPORATE	6,529	762	0	2,708	685	1,952	0	421
PERSONAL	15,774	14,870	0	889	0	0	14	0
AERIAL	3,310	0	2,979	86	0	0	245	0
INSTRUCTIONAL	5,154	4,909	0	168	0	0	78	0
AIR TAXI	9,517	2,665	0	3,807	1,332	286	286	1,142
OTHER	15,798	13,179	0	1,193	55	164	682	525

OPERATIONS (THOUSANDS) DURING PREVIOUS YEAR AS REPORTED ON JANUARY 1 OF DESIGNATED YEAR

1977

	TOTAL	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
TOTAL	109,616	82,959	4,825	11,297	2,734	1,606	3,589	2,607
BUSINESS	13,362	10,028	0	3,112	0	0	222	0
CORPORATE	6,394	610	0	2,656	1,244	1,191	0	692
PERSONAL	30,247	29,037	0	1,042	0	0	168	0
AERIAL	5,653	0	4,825	46	0	0	782	0
INSTRUCTIONAL	29,355	27,437	0	764	0	0	1,154	0
AIR TAXI	8,140	2,249	0	2,851	1,351	242	176	1,279
OTHER	16,458	13,599	0	825	138	174	1,087	635

1978

	TOTAL	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
TOTAL	111,581	83,018	4,996	12,326	3,191	1,708	3,874	2,469
BUSINESS	14,344	10,796	0	3,317	0	0	231	0
CORPORATE	6,933	708	0	2,894	1,242	1,400	0	689
PERSONAL	28,722	27,767	0	911	0	0	44	0
AERIAL	5,867	0	4,996	43	0	0	828	0
INSTRUCTIONAL	28,815	26,822	0	742	0	0	1,250	0
AIR TAXI	9,253	2,659	0	3,287	1,776	166	273	1,092
OTHER	17,646	14,266	0	1,131	172	141	1,247	689

1979

	TOTAL	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
TOTAL	121,260	90,236	5,277	13,576	3,412	1,925	4,054	2,780
BUSINESS	16,237	12,307	0	3,684	0	0	246	0
CORPORATE	7,474	783	0	3,079	1,257	1,579	0	776
PERSONAL	31,303	30,242	0	1,014	0	0	47	0
AERIAL	6,197	0	5,277	46	0	0	875	0
INSTRUCTIONAL	29,101	27,110	0	750	0	0	1,241	0
AIR TAXI	10,327	2,967	0	3,669	1,982	186	305	1,218
OTHER	20,620	16,827	0	1,335	172	161	1,340	785

OPERATIONS (THOUSANDS) DURING PREVIOUS YEAR AS REPORTED ON JANUARY 1 OF DESIGNATED YEAR

1980

	TOTAL	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
TOTAL	127,404	94,781	5,550	14,432	3,454	2,094	4,166	2,927
BUSINESS	17,911	13,608	0	4,041	0	0	262	0
CORPORATE	7,776	818	0	3,218	1,197	1,729	0	814
PERSONAL	32,794	31,675	0	1,070	0	0	50	0
AERIAL	6,518	0	5,550	48	0	0	920	0
INSTRUCTIONAL	29,430	27,436	0	759	0	0	1,235	0
AIR TAXI	10,861	3,121	0	3,859	2,085	195	320	1,281
OTHER	22,114	18,124	0	1,437	172	169	1,380	832

1981

	TOTAL	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
TOTAL	133,376	99,191	5,813	15,267	3,503	2,244	4,281	3,078
BUSINESS	19,487	14,822	0	4,393	0	0	273	0
CORPORATE	8,039	853	0	3,335	1,140	1,860	0	851
PERSONAL	34,264	33,087	0	1,125	0	0	52	0
AERIAL	6,828	0	5,813	50	0	0	964	0
INSTRUCTIONAL	29,697	27,696	0	766	0	0	1,234	0
AIR TAXI	11,413	3,279	0	4,055	2,191	205	337	1,346
OTHER	23,649	19,454	0	1,543	172	178	1,421	880

1982

	TOTAL	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
TOTAL	141,621	105,393	6,068	16,376	3,634	2,409	4,434	3,308
BUSINESS	21,277	16,204	0	4,787	0	0	285	0
CORPORATE	8,384	905	0	3,468	1,106	1,997	0	908
PERSONAL	36,302	35,039	0	1,209	0	0	55	0
AERIAL	7,126	0	6,068	52	0	0	1,006	0
INSTRUCTIONAL	30,006	27,993	0	775	0	0	1,238	0
AIR TAXI	12,276	3,527	0	4,361	2,356	221	362	1,448
OTHER	26,250	21,724	0	1,723	172	192	1,488	952

OPERATIONS (THOUSANDS) DURING PREVIOUS YEAR AS REPORTED ON JANUARY 1 OF DESIGNATED YEAR

1983

	TOTAL	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
TOTAL	155,785	115,686	6,311	18,482	4,098	2,691	4,734	3,662
BUSINESS	24,295	18,579	0	5,410	0	0	306	0
CORPORATE	9,153	1,029	0	3,726	1,151	2,206	0	1,041
PERSONAL	39,254	37,858	0	1,337	0	0	59	0
AERIAL	7,412	0	6,311	54	0	0	1,046	0
INSTRUCTIONAL	30,362	28,333	0	784	0	0	1,245	0
AIR TAXI	14,456	4,154	0	5,136	2,775	260	426	1,705
OTHER	30,854	25,655	0	2,035	172	225	1,651	1,116

1984

	TOTAL	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
TOTAL	169,530	125,523	6,545	20,649	4,479	2,988	4,955	4,353
BUSINESS	27,885	21,400	0	6,151	0	0	334	0
CORPORATE	9,848	1,134	0	3,996	1,136	2,439	0	1,143
PERSONAL	41,934	40,417	0	1,455	0	0	62	0
AERIAL	7,686	0	6,545	56	0	0	1,085	0
INSTRUCTIONAL	30,397	28,369	0	785	0	0	1,243	0
AIR TAXI	16,518	4,746	0	5,869	3,171	297	487	1,949
OTHER	35,261	29,457	0	2,336	172	252	1,783	1,261

1985

	TOTAL	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
TOTAL	188,128	138,920	6,767	23,630	5,072	3,365	5,335	5,039
BUSINESS	32,645	25,159	0	7,129	0	0	357	0
CORPORATE	10,753	1,274	0	4,333	1,145	2,724	0	1,276
PERSONAL	45,307	43,630	0	1,610	0	0	67	0
AERIAL	7,947	0	6,767	58	0	0	1,122	0
INSTRUCTIONAL	30,397	28,367	0	785	0	0	1,244	0
AIR TAXI	19,561	5,620	0	6,950	3,755	352	577	2,308
OTHER	41,519	34,869	0	2,765	172	289	1,968	1,455

OPERATIONS (THOUSANDS) DURING PREVIOUS YEAR AS REPORTED ON JANUARY 1 OF DESIGNATED YEAR

1986

	TOTAL	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
TOTAL	201,560	148,861	6,978	25,813	5,326	3,660	5,531	5,392
BUSINESS	36,867	28,438	0	8,053	0	0	376	0
CORPORATE	11,318	1,344	0	4,585	1,081	2,973	0	1,334
PERSONAL	47,716	45,926	0	1,719	0	0	71	0
AERIAL	8,196	0	6,978	60	0	0	1,157	0
INSTRUCTIONAL	30,296	28,266	0	782	0	0	1,248	0
AIR TAXI	21,213	6,095	0	7,537	4,072	381	626	2,502
OTHER	45,955	38,792	0	3,076	172	306	2,053	1,555

1987

	TOTAL	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
TOTAL	210,775	155,777	7,179	27,325	5,402	3,874	5,646	5,572
BUSINESS	40,128	30,927	0	8,816	0	0	385	0
CORPORATE	11,632	1,379	0	4,739	993	3,163	0	1,357
PERSONAL	49,456	47,585	0	1,797	0	0	74	0
AERIAL	8,431	0	7,179	62	0	0	1,190	0
INSTRUCTIONAL	30,058	28,029	0	776	0	0	1,254	0
AIR TAXI	22,073	6,342	0	7,842	4,237	397	651	2,604
OTHER	48,998	41,515	0	3,292	172	314	2,093	1,612

FEDERAL TAX REVENUE DURING PREVIOUS YEAR AS REPORTED ON JANUARY 1 OF DESIGNATED YEAR

1977	0
1978	86,311,587
1979	95,428,267
1980	101,973,353
1981	108,000,378
1982	115,484,205
1983	128,765,796
1984	142,703,905
1985	160,960,100
1986	175,016,900
1987	185,008,799

AIRCRAFT UTILIZATION RATE (HRS/AC/YR)

1977

	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
BUSINESS	156	0	193	0	0	187	0
CORPORATE	224	0	333	390	482	0	371
PERSONAL	104	0	139	0	0	25	0
AERIAL	0	304	169	0	0	294	0
INSTRUCTIONAL	386	0	282	0	0	278	0
AIR TAXI	480	0	538	1,610	676	658	604
OTHER	378	0	332	332	338	467	453

1978

	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
BUSINESS	156	0	192	0	0	173	0
CORPORATE	224	0	332	355	480	0	364
PERSONAL	104	0	139	0	0	25	0
AERIAL	0	289	160	0	0	306	0
INSTRUCTIONAL	408	0	305	0	0	274	0
AIR TAXI	537	0	583	1,864	479	836	527
OTHER	399	0	428	332	338	469	455

1979

	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
BUSINESS	156	0	192	0	0	167	0
CORPORATE	224	0	330	322	479	0	360
PERSONAL	104	0	139	0	0	25	0
AERIAL	0	294	180	0	0	304	0
INSTRUCTIONAL	423	0	429	0	0	252	0
AIR TAXI	477	0	531	1,484	737	564	651
OTHER	411	0	335	332	338	471	457

AIRCRAFT UTILIZATION RATE (HRS/AC/YR)

1980

	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
BUSINESS	156	0	191	0	0	162	0
CORPORATE	224	0	329	293	478	0	356
PERSONAL	104	0	139	0	0	25	0
AERIAL	0	291	178	0	0	301	0
INSTRUCTIONAL	422	0	453	0	0	254	0
AIR TAXI	449	0	500	1,395	693	530	613
OTHER	373	0	304	332	338	473	459

1981

	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
BUSINESS	156	0	191	0	0	154	0
CORPORATE	224	0	327	267	476	0	351
PERSONAL	104	0	139	0	0	25	0
AERIAL	0	289	177	0	0	299	0
INSTRUCTIONAL	421	0	553	0	0	256	0
AIR TAXI	459	0	511	1,427	709	542	627
OTHER	387	0	315	332	338	475	460

1982

	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
BUSINESS	156	0	190	0	0	138	0
CORPORATE	224	0	326	243	475	0	342
PERSONAL	104	0	139	0	0	25	0
AERIAL	0	287	175	0	0	297	0
INSTRUCTIONAL	423	0	581	0	0	257	0
AIR TAXI	515	0	573	1,600	795	608	702
OTHER	426	0	347	332	338	477	462

AIRCRAFT UTILIZATION RATE (HRS/AC/YR)

1983

	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
BUSINESS	156	0	189	0	0	126	0
CORPORATE	224	0	323	217	472	0	333
PERSONAL	104	0	139	0	0	25	0
AERIAL	0	285	174	0	0	295	0
INSTRUCTIONAL	419	0	661	0	0	256	0
AIR TAXI	547	0	609	1,704	845	646	747
OTHER	439	0	357	332	338	481	466

1984

	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
BUSINESS	156	0	188	0	0	112	0
CORPORATE	224	0	320	193	470	0	322
PERSONAL	104	0	139	0	0	25	0
AERIAL	0	283	173	0	0	293	0
INSTRUCTIONAL	414	0	684	0	0	255	0
AIR TAXI	550	0	612	1,712	850	650	751
OTHER	439	0	358	332	338	484	469

1985

	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
BUSINESS	156	0	187	0	0	106	0
CORPORATE	224	0	318	173	468	0	316
PERSONAL	104	0	139	0	0	25	0
AERIAL	0	282	172	0	0	292	0
INSTRUCTIONAL	412	0	761	0	0	256	0
AIR TAXI	523	0	581	1,627	807	617	713
OTHER	426	0	347	332	338	488	473

AIRCRAFT UTILIZATION RATE (HRS/AC/YR)

1986

	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
BUSINESS	156	0	186	0	0	103	0
CORPORATE	224	0	315	154	465	0	312
PERSONAL	104	0	139	0	0	25	0
AERIAL	0	280	171	0	0	290	0
INSTRUCTIONAL	408	0	793	0	0	257	0
AIR TAXI	459	0	510	1,426	708	542	626
OTHER	384	0	313	332	338	491	476

1987

	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
BUSINESS	156	0	186	0	0	93	0
CORPORATE	224	0	312	138	463	0	304
PERSONAL	104	0	139	0	0	25	0
AERIAL	0	279	171	0	0	289	0
INSTRUCTIONAL	406	0	870	0	0	258	0
AIR TAXI	493	0	549	1,532	761	582	673
OTHER	375	0	386	332	338	495	488

LOCAL AND ITINERANT OPERATIONS PLUS FLIGHT PLANS FILED AS REPORTED ON JANUARY 1 OF DESIGNATED YEAR

	LOCAL OPERATIONS THOUSANDS	ITINERANT OPERATIONS THOUSANDS	IFR FLIGHT PLANS THOUSANDS
1977	70,291	39,325	5,264
1978	70,357	41,224	5,721
1979	75,703	45,557	6,286
1980	79,036	48,368	6,646
1981	82,287	51,089	6,989
1982	86,887	54,733	7,446
1983	94,288	61,497	8,367
1984	101,212	68,318	9,289
1985	110,498	77,629	10,561
1986	117,235	84,325	11,442
1987	121,877	88,899	12,022

APPENDIX B.

AN EXAMPLE OF THE GENERAL AVIATION
DYNAMICS MODEL IN THE INTERACTIVE MODE

AN EXAMPLE OF THE GENERAL AVIATION DYNAMICS MODEL IN THE INTERACTIVE MODE

Sensitivity Analysis

In general, there are two ways to use model results or simulations - individually as projections and in pairs as sensitivity measures. Use of the model simply to make projections is fraught with dangers. Many potential users will not understand how the projections were derived and will expect unreasonable accuracy. The model is better used by employing extensive sensitivity analysis to evaluate a range of policies under a range of exogenous conditions. This process will identify the principal areas of model uncertainty and those portions of the model that deserve the greatest additional research.

The logical structure of the GAD model has been constructed such that relative comparisons can be made between the model forecasts from any two simulations. In particular, during a sensitivity analysis, absolute forecasts for each simulation are available, as well as percent deviations between the two cases. These deviations can be displayed over time either graphically or in tabular format.

A sensitivity analysis can be performed between any two simulations which are compatible with the model's capabilities. All GAD model output data from the first simulation are stored on a separate file. This base case need not be the "baseline" forecast representative of expected future conditions, but can be the result of any consistent set of conditions chosen by the analyst. Intermediate absolute forecast results from this base case can be obtained by the analyst, if desired. After obtaining all required intermediate output, the second simulation is specified and run. Absolute results of the second simulation are also available to the analyst. Sensitivity results are derived within the program logic by subtracting the results of the first simulation from the second simulation, dividing by the first simulation, and multiplying by 100 to convert differences to percent deviations from the base case; mathematically,

$$\%\ \text{Deviation} = \frac{AA(I,J)_2 - AA(I,J)_1}{AA(I,J)_1} \times 100$$

where,

$AA(I,J)_1$ = the number of active aircraft of type J within category I from the first (base) simulation

$AA(I,J)_2$ = the number of active aircraft of type J within category I from the second simulation

Values for these parameters are, of course, obtained at the same instant in time during their respective simulations.

Should conditions within the second simulation not change immediately from the base case, percent deviations, until the change becomes effective, will be zero. Furthermore, by continually computing these deviations over time, the non-linearity in model response is preserved. Most previous sensitivity analyses of general aviation activity were predicated on either linear or log-linear sensitivities.

An Example

The GAD model uses the interactive dialogue feature of NUCLEUS to guide the analyst through a series of procedures and options. This technique eliminates the need for preliminary calculations by the user. Simple yes/no responses to NUCLEUS questions establish the conditions of the particular simulation to be run. If the user is uncertain of the parameter values contained in the model, NUCLEUS will display them. If the user desires to change these values, NUCLEUS will accept the new values. Incorrect (or unexpected) responses to NUCLEUS questions will simply cause the same question to be repeated.

A sensitivity example, comparing the normal "baseline" forecast to an increased fuel tax (effective January 1, 1979), is discussed below. This example was run on the UCS computer. Not all the options available for input/output are displayed; only enough to illustrate the procedures. In this example, all user entries are underlined.

Following the usual log-in procedures and LOAD GAD, the computer will respond

YOU ARE ENTERING THE GENERAL AVIATION DYNAMICS MODEL CREATED AT BATTELLE COLUMBUS LABORATORIES, WRITTEN IN THE MODELING LANGUAGE NUCLEUS. IN THIS SESSION YOU WILL PROJECT CERTAIN LEVELS OF GENERAL AVIATION ACTIVITY FOR THE YEARS 1977 TO 1987.

ENTER ENDING YEAR FOR SIMULATION
?

Any year between 1977 and 1987 is an acceptable response; the simulation will be from 1977 through the year specified and the results will be reported for that range of years. A response within the acceptable range

<u>1980</u>

allows the system to continue with

Step 1 -- WOULD LIKE TO COMPUTE THE FORECAST WITH THE INITIAL ASSUMPTIONS UNCHANGED (YES OR NO) OR VIEW THE STEPS OF THIS MODEL (TEACH)
?

The response

<u>TEACH</u>

causes the steps of the model to be printed and then the question to be repeated. "Teach" also causes the steps of the model to be printed out as those steps are executed

STEP 1 -- COMPUTE THE FORECAST USING THE INITIAL ASSUMPTIONS UNCHANGED.
STEP 2 -- DISPLAY AND/OR CHANGE INITIAL ASSUMPTIONS.
STEP 3 -- COMPUTE THE FORECAST OF GENERAL AVIATION ACTIVITY.
STEP 4 -- PRINT TABLES OF RESULTS OF THE FORECAST.
STEP 5 -- PLOT THE RESULTS OF THE FORECAST.
STEP 6 -- COMPARE THE RESULTS OF THE PRESENT FORECAST TO THOSE OF A PREVIOUS FORECAST FOR SENSITIVITY ANALYSIS.
STEP 7 -- PRINT TABLES FOR SENSITIVITY ANALYSIS.
STEP 8 -- PLOT THE RESULTS OF SENSITIVITY ANALYSIS.
STEP 9 -- SAVE THE RESULTS OF THIS FORECAST FOR FUTURE SENSITIVITY ANALYSIS.

STEP 1 -- WOULD YOU LIKE TO COMPUTE THE FORECAST WITH THE INITIAL ASSUMPTIONS UNCHANGED (YES OR NO) OR VIEW THE STEPS OF THIS MODEL (TEACH)
?

Now the appropriate response to the question is either YES or NO; a response of

<u>YES</u>

causes the normal "baseline" simulation to be executed. Since the TEACH flag was set on by the TEACH request, the steps are printed out as they are executed

STEP 3 -- THE FORECAST OF GENERAL AVIATION ACTIVITY IS BEING COMPUTED.

Having executed the simulation the system prints,

STEP 4 -- PRINT TABLES OF RESULTS OF THE FORECAST.

and then asks the question

DO YOU WANT TO SEE TABLES OF RESULTS OF THE FORECAST
?

The response

<u>YES</u>

causes the system to ask

WHAT OUTPUT TABLE WOULD YOU LIKE, OR ENTER LIST OR NONE.
?

The unfamiliar user will not know the available tabular output options. By responding

<u>LIST</u>

the following list of output table options will be printed.

IDENTIFIER	DESCRIPTION
AA1	ACTIVE AIRCRAFT BY YEAR
AA2	ACTIVE AIRCRAFT BY USER CATEGORY
AIRPORTS	LOCAL AND ITINERANT OPERATIONS PLUS IFR FLIGHT PLANS FILED
AIRUTIL	AIRCRAFT UTILIZATION RATES
ECONOMIC	DPI,GNP,RAD
FIXEDCOST	FIXED COST
VARCOST	VARIABLE COST
FUEL	FUEL CONSUMED IN MILLIONS OF GALLONS
HOURSFLOWN	HOURS FLOWN IN THOUSANDS
OPERATIONS	TOTAL OPERATIONS, IN THOUSANDS
PILOTS	SP,PP,CP,ATP,P,HP,TP,IP,HR,THP
REVENUE	FEDERAL TAX REVENUE
TOTALS	TOTAL AIRCRAFT, TOTAL HOURS FLOWN, TOTAL OPERATIONS

When the list is complete, the previous question will be repeated:

WHAT OUTPUT TABLE WOULD YOU LIKE, OR ENTER LIST OR NONE.
?

A response of

PILOTS

will generate the following table

GENERAL AVIATION DYNAMICS MODEL PAGE 1

PILOT DATA, 1977 TO 1980

	1977	1978	1979	1980
STUDENT PILOTS	188,801	183,794	183,654	183,176
PRIVATE PILOTS	309,005	323,821	335,104	344,608
COMMERCIAL PILOTS	187,801	189,699	192,068	195,342
AIR TRANSPORT PILOTS	45,072	47,784	50,879	53,766
PILOT SUBTOTAL	730,679	745,098	761,705	776,891
HELICOPTER PILOTS	4,804	4,333	3,940	3,608
TOTAL PILOTS	735,483	749,431	765,645	780,499
INSTRUMENT RATINGS	211,364	221,497	232,437	243,969
HELICOPTER RATINGS	23,012	24,395	25,739	27,052
TOTAL HELIC RATINGS	27,816	28,728	29,679	30,659

Note that the table is printed for only the requested years, 1977-1980. Upon completion of the requested output table, the same question is repeated.

WHAT OUTPUT TABLE WOULD YOU LIKE, OR ENTER LIST OR NONE.
?

The user may request as many of the table options as he wants. When no more tabular data is required the response is

NONE

Since the TEACH flag is on, the computer prints the next step in the model,

STEP 5 -- PLOT THE RESULTS OF THE FORECAST.

and then asks the question

DO YOU WANT TO SEE PLOTS OF RESULTS OF THE FORECAST
?

By answering

YES

the computer responds

WHAT PLOT WOULD YOU LIKE. ENTER THE VARIABLE, OR LIST, OR NONE
?

Not being familiar with the plot options the user responds

LIST

which will generate the following list of variables:

IDENTIFIER	DESCRIPTION
AA	NUMBER OF ACTIVE AIRCRAFT
AASUM	TOTAL NUMBER OF AIRCRAFT
ATP	AIRLINE TRANSPORT PILOTS
AUR	AIRCRAFT UTILIZATION RATE (HRS/AC/YR)
CP	COMMERCIAL PILOTS
DPI	DISPOSABLE PERSONAL INCOME (1972 $, 1972=1)
FC	FUEL CONSUMED (MILLION GALLONS)
FIX	FIXED COST INDEX ($/HR), (1972 $, 1972=1)
FTR	FEDERAL TAX REVENUE (MILLION DOLLARS)
GNP	GROSS NATIONAL PRODUCT (1972 $, 1972=1)
HF	HOURS FLOWN (THOUSANDS)
HFSUM	TOTAL HOURS FLOWN (THOUSANDS)
HP	HELICOPTER PILOTS
HR	HELICOPTER RATINGS
IP	INSTRUMENT RATINGS
OPS	OPERATIONS (THOUSANDS)
OPSUM	TOTAL OPERATIONS (THOUSANDS)
P	PILOT SUBTOTAL
PP	PRIVATE PILOTS
RAD	REVENUE AIRCRAFT DEPARTURES (1972 $, 1972=1)
SP	STUDENT PILOTS
TC	TOTAL COST
THP	TOTAL HELICOPTER RATINGS
TP	TOTAL PILOTS
VC	VARIABLE COST INDEX ($/HR), (1972 $, 1972=1)

followed by a repeat of the question

WHAT PLOT WOULD YOU LIKE. ENTER THE VARIABLE, OR LIST, OR NONE
?

Any variable identifier from the above list can be specified. For example, in order to plot the total number of aircraft, the user responds

AASUM

Now the computer will ask

PLOT THIS VARIABLE AGAINST TIME OR ANOTHER VARIABLE OR LIST
?

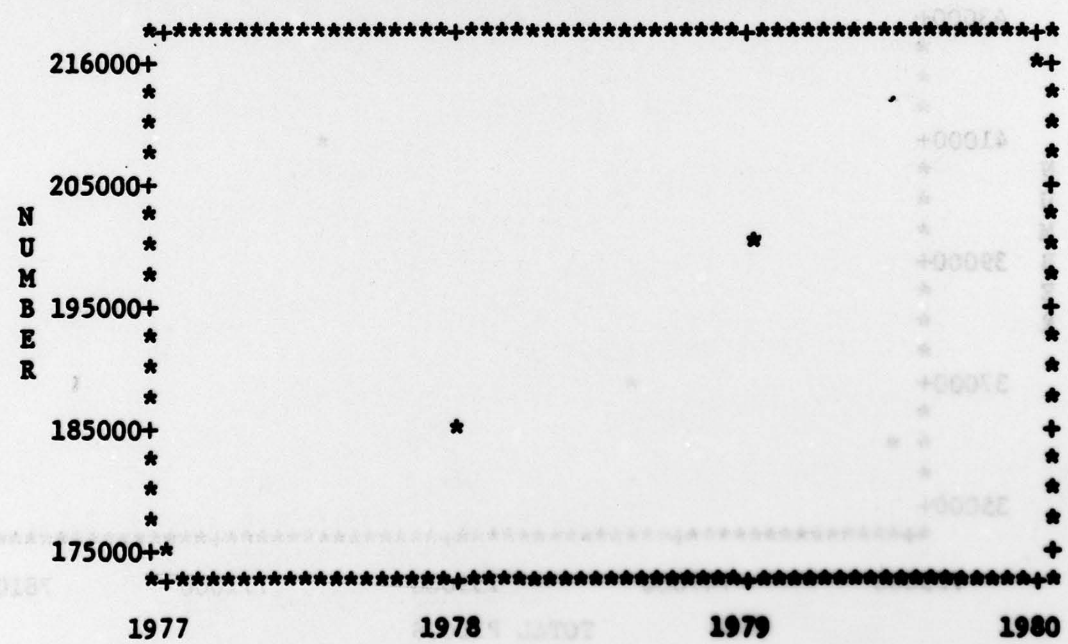
By responding

TIME

the following plot will be displayed,

GENERAL AVIATION DYNAMICS MODEL PAGE 2

TOTAL NUMBER OF AIRCRAFT, 1977 TO 1980



Upon completion of the plot the computer will again ask

WHAT PLOT WOULD YOU LIKE. ENTER THE VARIABLE, OR LIST, OR NONE
?

Enter the next variable to be plotted

<u>**HFSUM**</u>

Now the computer will ask

PLOT THIS VARIABLE AGAINST TIME OR ANOTHER VARIABLE OR LIST
?

To plot the total hours flown against the number of pilots, enter

<u>**TP**</u>

The following plot will be displayed

```
                                        GENERAL AVIATION DYNAMICS MODEL PAGE 3

                      TOTAL PILOTS VS TOTAL HOURS FLOWN (THOUSANDS), 1977 TO 1980

            *+***************+**************+***************+***************+*
       43000+                                                              *+
            *                                                               *
            *                                                               *
            *                                                               *
       41000+                                       *                       +
   N        *                                                               *
   U        *                                                               *
   M        *                                                               *
   B   39000+                                                               +
   E        *                                                               *
   R        *                                                               *
            *                                                               *
       37000+          *                                             1      +
            *                                                               *
            * *                                                             *
            *                                                               *
            *                                                               *
       35000+                                                               +
            *+***************+**************+***************+***************+*
          735000          747000         759000          771000         781000
                                     TOTAL PILOTS
```

Again the computer will ask

WHAT PLOT WOULD YOU LIKE. ENTER THE VARIABLE, OR LIST, OR NONE
?

Entering

<u>**NONE**</u>

will cause the computer to print

STEP 9 -- SAVE THE RESULTS OF THIS FORECAST FOR FUTURE SENSITIVITY ANALYSIS.

followed by

WOULD YOU LIKE TO SAVE THE RESULTS OF THIS SESSION FOR LATER SENSITIVITY ANALYSIS
?

When performing a sensitivity analysis, any simulation run may become the baseline for future comparison. If the current run is desired to be a baseline for comparisons, enter

<u>**YES**</u>

The computer will save the results of the current run and respond

WOULD YOU LIKE TO CONTINUE WITH ANOTHER FORECAST
?

The reply

<u>**YES**</u>

will cause the computer to print

ENTER ENDING YEAR FOR SIMULATION
?

Entering a valid year

<u>**1980**</u>

allows the system to continue with

STEP 1 -- WOULD YOU LIKE TO COMPUTE THE FORECAST WITH THE INITIAL ASSUMPTIONS UNCHANGED (YES OR NO) OR VIEW THE STEPS OF THIS MODEL (TEACH)
?

Since we are now familiar with the steps of the model we do not need to set the TEACH flag on. Answer

NO

since we already have stored the results of the simulation with the initial assumptions unchanged. The computer will ask

ENTER NAME OF VARIABLE TO BE CHANGED, OR LIST, OR NONE
?

The user has already decided that the second simulation will involve a fuel tax increase, but does not know how to implement that in the model. Therefore answer

LIST

which will generate the following list:

AIRCRAFT VARIABLES

IDENTIFIER	DESCRIPTION
ADRN	AIRCRAFT DESTRUCTION RATE, NORMALIZED (AC/YR)
FC	FIXED COST INDEX (1972 $, 1972=1). ONE COMPONENT OF FC IS THE ANNUALIZED INVESTMENT
FCINF	FIXED COST INFLATION FACTOR
VC	VARIABLE COST INDEX ($/HR), (1972 $, 1972=1). COMPONENTS OF VC ARE FTAX (FEDERAL FUEL TAX) AND LFEE (LANDING FEE).
VCINF	VARIABLE COST INFLATION FACTOR
FHRF	FLYING HOURS REQUIRED FACTOR

ECONOMIC VARIABLES

IDENTIFIER	DESCRIPTION
DPI	DISPOSABLE PERSONAL INCOME (1972 $, 1972=1)
GNP	GROSS NATIONAL PRODUCT (1972 $, 1972=1)
RAD	REVENUE AIRCRAFT DEPARTURES (1972=1)
ECONOMIC	DPI, GNP, RAD

FUEL VARIABLES

IDENTIFIER	DESCRIPTION
SFC	SPECIFIC FUEL CONSUMPTION

PILOT VARIABLES

IDENTIFIER	DESCRIPTION
ATPDN	AIRLINE TRANSPORT PILOT DEPARTURE RATE, NORMALIZED
CPDN	COMMERCIAL PILOT DEPARTURE RATE, NORMALIZED
IPDN	INSTRUMENT PILOT DEPARTURE RATE, NORMALIZED
PCIN	PRIVATE CERTIFICATES ISSUED RATE, NORMALIZED
PPDN	PRIVATE PILOTS DEPARTURE RATE, NORMALIZED
SPDN	STUDENT PILOTS DEPARTURE RATE, NORMALIZED
URIPN	UPGRADE TO INSTRUMENT PILOT RATE, NORMALIZED
SCIX	STUDENT CERTIFICATES ISSUED MULTIPLIER
PILOT	ATPDN, CPDN, IPDN, PCIN, PPDN, SPDN, URIPN

Upon completion of the list, the computer will repeat the question

ENTER NAME OF VARIABLE TO BE CHANGED, OR LIST OR NONE
?

The user can see from the above list that the federal fuel tax is a component of VC the variable cost index and so enters

VC

The computer responds by displaying the current values of the variable cost index components

```
THE COMPONENTS OF THE VARIABLE COST INDEX ARE FTAX, THE FEDERAL FUEL TAX, AND
LFEE, THE LANDING FEE
THE CURRENT VALUES FOR THE VARIABLE COST INDEX COMPONENTS ARE
                         FEDERAL FUEL TAX ($/GAL)
```

	AV GAS	JET FUEL
1977	0.07	0.07
1978	0.07	0.07
1979	0.07	0.07
1980	0.07	0.07

LANDING FEE ($/LANDING)

	SNGL-P NON-AER	SNGL-P AER	MULTI-PISTON	TURBO PROP	TURBO JET	PISTON HELIC	TURBINE HELIC
1977	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1978	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1979	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1980	0.00	0.00	0.00	0.00	0.00	0.00	0.00

and then asks

```
DO YOU WISH TO CHANGE THE VALUES OF FTAX, LFEE OR NONE
    ?
```

To change the fuel tax values the user enters

<u>FTAX</u>

and the computer responds

```
WHAT YEAR WOULD YOU LIKE THE NEW FUEL TAX TO BEGIN
    ?
```

For a January 1, 1979 date of effectiveness enter

<u>1979</u>

The computer will ask

```
WOULD YOU LIKE THE FUEL TAX TO REMAIN CONSTANT FOR ALL SUBSEQUENT YEARS
    ?
```

If the desired fuel tax change is to increase the fuel tax by 5¢ a year, the answer is

NO

The computer will ask

WOULD YOU LIKE THE FUEL TAX TO CHANGE AT A CONSTANT RATE FOR ALL SUBSEQUENT YEARS
?

Again the answer is

NO

The computer will respond by asking for the fuel tax values to be entered explicitly for each year, starting with the year of the change

ENTER FUEL TAX VALUES, IN DOLLARS, FIRST FOR AVIATION GAS, THEN FOR JET FUEL. ENTER VALUES FOR EACH YEAR.
?

The 1979 fuel tax values are entered first

0.12 0.12

The computer then asks for the values for the next year

?

and the values for 1980 are entered

0.17 0.17

Since this simulation is to end in 1980 no more values are required. The computer then displays the new values of the fuel tax

THE NEW VALUES FOR THE FUEL TAX ARE
FEDERAL FUEL TAX ($/GAL)

	AV GAS	JET FUEL
1977	0.07	0.07
1978	0.07	0.07
1979	0.12	0.12
1980	0.17	0.17

and then repeats the question

DO YOU WISH TO CHANGE THE VALUES OF FTAX, LFEE OR NONE
?

Since the new fuel tax has been entered as desired and the user does not want to impose a landing fee, enter

NONE

The computer then asks whether any other variables are to be changed

ENTER NAME OF VARIABLE TO BE CHANGED, OR LIST, OR NONE
?

Since no other variables are to be changed enter

NONE

Since there are no more changes, the simulation is run. On finishing execution of the simulation the computer asks

DO YOU WANT TO SEE TABLES OF RESULTS OF THE FORECAST
?

Responding

YES

the computer then asks

WHAT OUTPUT TABLE WOULD YOU LIKE, OR ENTER LIST OR NONE.
?

Responding as for the first simulation,

PILOTS

will generate the following table

GENERAL AVIATION DYNAMICS MODEL PAGE 4

PILOT DATA, 1977 TO 1980

	1977	1978	1979	1980
STUDENT PILOTS	188,801	183,794	183,654	179,129
PRIVATE PILOTS	309,005	323,821	335,104	345,428
COMMERCIAL PILOTS	187,801	189,699	192,068	194,521
AIR TRANSPORT PILOTS	45,072	47,784	50,879	53,766
PILOT SUBTOTAL	730,679	745,098	761,705	772,844
HELICOPTER PILOTS	4,804	4,333	3,940	3,534
TOTAL PILOTS	735,483	749,431	765,645	776,378
INSTRUMENT RATINGS	211,364	221,497	232,437	243,148
HELICOPTER RATINGS	23,012	24,395	25,739	27,052
TOTAL HELIC RATINGS	27,816	28,728	29,679	30,586

Upon completion of the table the computer will again ask

WHAT OUTPUT TABLE WOULD YOU LIKE, OR ENTER LIST OR NONE.
?

If no more output tables are desired, enter

NONE

The computer will ask

DO YOU WANT TO SEE PLOTS OF RESULTS OF THE FORECAST
?

Responding

NO

will cause the computer to ask

DO YOU WANT SENSITIVITY ANALYSIS, (THE PREVIOUSLY SAVED FORECAST IS THE BASELINE), (YES OR NO)
?

Answer

YES

The computer will ask

WHAT OUTPUT TABLE WOULD YOU LIKE, OR ENTER LIST OR NONE
?

The list of output tables for sensitivity analyses is a subset of the list for absolute forecasts. Therefore, the unfamiliar user should enter

LIST

which will generate the following list of output tables

TABLE	VARIABLES IN TABLE
AA1	ACTIVE AIRCRAFT BY YEAR
AA2	ACITIVE AIRCRAFT BY USER CATEGORY
AIRPORTS	LOCAL AND ITINERANT OPERATIONS PLUS IFR FLIGHT PLANS FILED
AIRUTIL	AIRCRAFT UTILIZATION RATES
FUEL	FUEL CONSUMED
HOURSFLOWN	HOURS FLOWN
OPERATIONS	TOTAL OPERATIONS
PILOTS	SP,PP,CP,ATP,P,HP,TP,IP,HR,THP
REVENUE	FEDERAL TAX REVENUE
TOTALS	TOTAL AIRCRAFT, TOTAL HOURS FLOWN, TOTAL OPERATIONS

The computer will then repeat the question

WHAT OUTPUT TABLE WOULD YOU LIKE, OR ENTER LIST OR NONE
?

By responding

PILOTS

the following table of percent deviations will be generated

GENERAL AVIATION DYNAMICS MODEL PAGE 5

PILOT DATA, PERCENT DEVIATION FROM BASELINE, 1977 TO 1980

	1977	1978	1979	1980
STUDENT PILOTS	0.00	0.00	0.00	-2.21
PRIVATE PILOTS	0.00	0.00	0.00	0.24
COMMERCIAL PILOTS	0.00	0.00	0.00	-0.42
AIR TRANSPORT PILOTS	0.00	0.00	0.00	0.00
PILOT SUBTOTAL	0.00	0.00	0.00	-0.52
HELICOPTER PILOTS	0.00	0.00	0.00	-2.05
TOTAL PILOTS	0.00	0.00	0.00	-0.53
INSTRUMENT RATINGS	0.00	0.00	0.00	-0.34
HELICOPTER RATINGS	0.00	0.00	0.00	0.00
TOTAL HELIC RATINGS	0.00	0.00	0.00	-0.24

Note that since the pilot data reported in 1979 is for the year 1978 as reported on January 1, 1979, the effects of the changed fuel tax in 1979 are not felt until the 1980 pilot data. The computer will again ask

WHAT OUTPUT TABLE WOULD YOU LIKE, OR ENTER LIST OR NONE
?

If no more sensitivity output tables are desired, enter

NONE

The computer will ask

DO YOU WANT TO SEE PLOTS OF THE SENSITIVITY ANALYSIS RESULTS
?

If sensitivity plots are desired enter

YES

The computer will ask

```
WHAT SENSITIVITY PLOT WOULD YOU LIKE.  ENTER THE VARIABLE, OR LIST, OR NONE
     ?
```

To obtain the list of possible sensitivity plots enter

<u>LIST</u>

and the computer will generate the following list

IDENTIFIER	DESCRIPTION
AA	ACTIVE AIRCRAFT BY PRIMARY USE DURING PREVIOUS YEAR, AS REPORTED ON JANUARY 1 OF DESIGNATED YEAR, AS PERCENT DEVIATION FROM BASELINE
AASUM	TOTAL AIRCRAFT
ATP	AIR TRANSPORT PILOTS
CP	COMMERCIAL PILOTS
FC	FUEL CONSUMED DURING PREVIOUS YEAR, AS REPORTED ON JANUARY 1 OF DESIGNATED YEAR, AS PERCENT DEVIATION FROM BASELINE
FTR	FEDERAL TAX REVENUE DURING PREVIOUS YEAR, AS REPORTED ON JANUARY 1 OF DESIGNATED YEAR, AS PERCENT DEVIATION FROM BASELINE
HFSUM	TOTAL HOURS FLOWN
HP	HELICOPTER PILOTS
HR	HELICOPTER RATINGS
IP	INSTRUMENT RATINGS
OPS	OPERATIONS (THOUSANDS) DURING PREVIOUS YEAR, AS REPORTED ON JANUARY 1 OF DESIGNATED YEAR, AS PERCENT DEVIATION FROM BASELINE
OPSUM	TOTAL OPERATIONS
PP	PRIVATE PILOTS
P	PILOT SUBTOTAL
SP	STUDENT PILOTS
TC	TOTAL COST, AS PERCENT DEVIATION FROM BASELINE
THP	TOTAL HELIC RATINGS
TP	TOTAL PILOTS

Upon completion of the list the computer will repeat the question

```
WHAT SENSITIVITY PLOT WOULD YOU LIKE.  ENTER THE VARIABLE, OR LIST, OR NONE
     ?
```

To see the effect of the changed fuel tax on the fuel consumption, enter

<u>FC</u>

The computer will respond

PLEASE ENTER EITHER 1 FOR AVIATION GAS OR 2 FOR JET FUEL FOR THE PLOT
?

For aviation gas, enter

1

and the computer will generate the following sensitivity plot

```
                              GENERAL AVIATION DYNAMICS MODEL PAGE 6

                  FUEL CONSUMED DURING PREVIOUS YEAR, AS REPORTED ON
                  JANUARY 1 OF DESIGNATED YEAR, AS PERCENT DEVIATION
                  FROM BASELINE, 1977 TO 1980

                                AVIATION GAS

          *+*******************+*******************+*******************+*
   0.00+*                      *                   *                   +
         *                                                             *
         *                                                             *
         *                                                             *
  -0.09+                                                               +
P        *                                                             *
E        *                                                             *
R        *                                                             *
C -0.19+                                                               +
E        *                                                             *
N        *                                                             *
T        *                                                             *
  -0.29+                                                               +
         *                                                             *
         *                                                             *
         *                                                             *
  -0.39+                                                              *+
          *+*******************+*******************+*******************+*

         1977                 1978                1979               1980

                                   YEAR
```

Upon completing the plot the computer will repeat the question

WHAT SENSITIVITY PLOT WOULD YOU LIKE. ENTER THE VARIABLE, OR LIST, OR NONE
?

For no further sensitivity plots enter

NONE

The computer will ask

WOULD YOU LIKE TO SAVE THE RESULTS OF THIS SESSION FOR LATER SENSITIVITY ANALYSIS
?

If the previous run is not to become a new baseline enter

NO

The computer will ask

WOULD YOU LIKE TO CONTINUE WITH ANOTHER FORECAST
?

If no more forecasts are desired, enter

NO

The computer will respond

YOU ARE NOW LEAVING THE GENERAL AVIATION DYNAMICS MODEL.

and return the user to the interactive session with the computer for log-out. On the UCS computer the computer responds

END UNICMD

and the user can log-out by entering

BYE

The above interactive session was run on the UCS computer. The only difference between it and a similar run on the Battelle computer, apart from the log-in and log-out procedures, is in the occurrence of a / as a user prompt instead of ? as above.

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